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Results and Observations in 2001 and 2002

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Kevin Boothroyd, Rob Robinson, Ed Theobald and Rashpal Rai - Envirotest Canada.

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Printed in Canada

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Foreword

The AirCare program underwent significant changes from September of 1999 through December of 2000. Starting on January 1, 2001 a new era for the program began with the introduction of the IM240 test procedure. Adopting this test procedure allowed for biennial testing of newer technology vehicles, responding to public concerns about the necessity of testing vehicles in the early stage of their lives. The increased stringency of the IM 240 test allows for reduced testing frequency without a loss of program effectiveness.

Over the past two years, AirCare inspections have continued to be effective in identifying excess-emitting vehicles. In fact, over 200,000 vehicles failed inspection in calendar years 2001 and 2002 combined. This figure underscores the need for some form of regular testing to counteract emission increases that are otherwise inevitable as vehicles age and critical components degrade or fail altogether. Although the vehicle manufacturers have made great strides in improving the effectiveness and durability of emission controls, the practical lifespan of most vehicles greatly exceeds the age and mileage limits that new-vehicle emission control systems were designed for. In-use inspection and maintenance programs become very important in keeping in check the emissions of vehicles that are well beyond their design durability limits.

Technological improvements to the inspection process have kept the AirCare program at the forefront of inspection and maintenance programs. We believe that the program is better equipped than most, if not all, other inspection and maintenance programs for the task of identifying excess-emitting vehicles. However, the emission reduction benefits of the program are derived primarily from the repairs made to failing vehicles. Since its inception, the AirCare program has included a component that deals with the training, certification and monitoring of the repair industry. To keep pace with the advancements on the inspection side of the program, AirCare introduced a web-based application called RepairNet. This system provides the repair industry with comprehensive test and repair history for all vehicles and copious amounts of diagnostic information for each failed test. Although the industry has apparently accepted the new system, the amount and quality of repair data submitted has been disappointing. It appears that only one in three failed vehicles is handled by the certified repair industry. A further concern is that 30% of vehicles repaired by certified repair facilities do not pass re-inspection.

As the program moves into the last three years of the current contract, greater emphasis will be placed on improving our understanding of how vehicle owners respond when their vehicles fail an AirCare inspection and what influences their decision to seek repairs from a certified or non-certified repair shop. Our goal for the near future is to enhance the effectiveness of the industry by increasing the amount of repair data collected and the percentage of vehicles that successfully pass re-inspection. By achieving these goals, AirCare will continue to be one of the best I/M programs in the world.

M.A. (Martin) Lay
Chief Executive Officer
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1.0 EXECUTIVE SUMMARY

Inspection and maintenance programs continue to be important components of air pollution reduction strategies in many cities around the world. The basic premise of all I/M programs is that a minority of excess-emitting vehicles contribute disproportionately to the inventory of smog-forming pollutants (hydrocarbons and oxides of nitrogen) and carbon monoxide. Identifying these vehicles and requiring that they be effectively repaired produces worthwhile emission reductions at a reasonable cost-benefit ratio.

In order to evaluate the effectiveness of any I/M program, there are two key factors that must be examined:

- The efficiency of the program in identifying the excess-emitting vehicles.
- The effectiveness of the repairs performed by the repair sector in reducing the emission rate of failing vehicles.

It is estimated that there are 1.2 million light-duty passenger vehicles and trucks registered in the Lower Mainland of British Columbia. Since AirCare testing is not required for vehicles less than two years old, approximately 150,000 vehicles are exempt at any given time for this reason. Due to the introduction of biennial testing for vehicles of 1992 model year and newer, the number of vehicles tested at AirCare inspection centres dropped from just under 1 million in 2000 to 748,068 in 2001 and 778,521 in 2002. With re-inspections, the total number of inspections exceeded the number of vehicles tested by 134,673 in 2001 and 176,077 in 2002. In 2001, 114,189 vehicles failed inspection and 127,436 failed in 2002. This represents 15.26% and 16.36% of the vehicles tested in each year.

Due to the electronic link between the vehicle registration system and the AirCare database, the compliance rate for the program is very high. A comparison of ICBC registration data and AirCare inspection statistics indicates that virtually every registered vehicle that required an AirCare inspection appeared at an inspection facility.

Vehicles from the 1991-and-older age group accounted for the majority of failures in both years, despite accounting for about one third of vehicle registrations. In 2001, 69% of failed vehicles were 1991 models or older. In 2002, the proportion was 58%. Using vehicle population and odometer reading data, it is estimated that the 1991-and-older group accounted for 33% of all vehicle-kilometres-travelled (VkmT) in 2001 and 29% in 2002. Despite accounting for a minority of the total VkmT, 1991-and-older vehicles accounted for 64% - 79% of total light-duty vehicle-related emissions of VOCs, CO and NO_x in 2001 (depending on the pollutant) and 62% - 76% in 2002.

1.1 AIRCARE BENEFITS

1.1.1 DIRECT BENEFITS FROM VEHICLE REPAIRS

The data indicate that approximately 63,000 vehicles passed after failing their initial AirCare tailpipe emissions test in 2001 along with another 77,000 in 2002. It is assumed in this report that all of these "re-inspected to pass" vehicles experienced a reduction in emissions as a result

of repairs performed after the failing inspection, even though the only vehicles for which it can be said with certainty that repairs were performed are those that went to AirCare Certified facilities and had repair data submitted on-line to the AirCare database. In 2001, 21,295 vehicles passed re-inspection with confirmed repairs. The corresponding number for 2002 was 24,805. These totals represent only about 33% of all "re-inspected-to-pass" vehicles. It is possible that certified repair shops repaired more vehicles than this but chose not to submit repair data. Anecdotal reports from the certified repair industry suggest that some technicians submit repair data only when they believe that there is a strong possibility that a vehicle will fail the re-inspection and they want to make sure that their customer receives at least a Conditional Pass. There is little other incentive for a repair technician to submit repair data unless they are in their last year of certification (technicians are certified for 3 years at a time). In their last year of certification, technicians will be motivated to submit repair data for those vehicles that they believe will do well on re-inspection, because they can be automatically re-certified if their repair effectiveness performance meets or exceeds the overall industry average. They will be reluctant to issue too many Conditional Passes during this period as this will lower their average repair effectiveness rating.

Any vehicle repaired at a Certified AirCare repair centre is eligible for a Conditional Pass as long as repair data has been submitted. There were 9,883 Conditional Passes issued in 2001 and 11,469 in 2002. This represents about 30% of all vehicles repaired at certified repair centres and about 10% of all failing vehicles.

Substantial reductions in emissions were evident for vehicles that successfully passed re-inspection. Reductions in hydrocarbon emissions were typically the greatest, while NO_x reductions were the least. Among the oldest vehicles (pre-1972), repairs consistently increased NO_x emissions.

As a result of the ongoing sampling test program initiated in 2001 (based on full-duration IM240 testing in the inspection lanes), a database of almost 9,000 mass emission test results was available to support the calculation of program benefits. This represents an order of magnitude increase compared to the number of HOT505 emission data samples used in previous analyses. Within the mass emission sample, there were 886 failing and 766 post-repair inspection results. After subdividing the mass emission sample group by age/technology group and failure mode, corresponding post-repair results were categorized as either "good" or "marginal" depending on how post-repair emissions results compared to those of normal passing vehicles. It was then possible to apply mass emission credits to the overall population of failing vehicles by identifying the age/technology grouping, failure mode, and the noted improvement in ASM or IM240 inspection results after repair and cross-referencing to the mass emission data table. Vehicle-kilometres-travelled data were then applied to weight the improvement according to the amount of expected use the vehicle would receive in the ensuing year.

Although this is essentially the same methodology used in previous studies of program effectiveness, the use of IM240-based emission factors instead of HOT505 data changed the calculated values for total fleet mass emissions. However, an analysis of HOT505 and IM240 test results performed on the same vehicles concluded that the *relative* differences between pre- and post-repair inspections were comparable, regardless of the test type. Due to the fact that IM240 emission factors are based on a hot-start test and do not consider cold-start and off-cycle driving, the MOBILE 6 inventory model was used to generate the tonnage of each pollutant by applying percentage reductions from IM240-based data to MOBILE 6 generated inventory data.

Based on the above-mentioned methodology, the emission reductions directly related to AirCare-related repairs were calculated as shown in the table below:

Emission Reductions in 2001 and 2002

	2001	2002
HC	13% (1,262 tonnes)	15% (1,338 tonnes)
CO	8% (9,068 tonnes)	10% (10,440 tonnes)
NO_x	5% (506 tonnes)	7% (594 tonnes)

1.1.2 VEHICLES REMOVED FROM USE

In addition to the benefits indicated by pre- and post-repair test results, there were 22,604 vehicles that failed in 2001 and did not return for re-inspection in that year. In 2002, 24,355 vehicles failed an AirCare inspection but did not appear for re-inspection within the calendar year. These vehicles are likely to have been scrapped, placed in storage, or sold outside the AirCare area. It is recognized that some portion of these vehicles may still be in use as a result of finding administrative routes around the program requirements, but the apparent incidence of registering vehicles outside the AirCare territory, yet actually continuing to operate them in the area, is negligible. Checking vehicle licensing records of a random sample of apparently-retired vehicles indicates that in virtually all cases, the vehicles were no longer licensed anywhere in British Columbia.

The removal of high-emitting vehicles from the fleet produces a significant emissions benefit. Some portion of this emission reduction should be counted as part of the AirCare program benefits, but only a portion – not all. Since some or all of the retired vehicles might have dropped out of the fleet anyway, even with no AirCare program, it is difficult to say precisely what proportion of the benefit should be attributed to the program. In the extreme, the benefits attributable to the retirement of all of the vehicles in 2001 amounts to 2,338 tonnes of HC, 20,847 tonnes of CO and 1,284 tonnes of NO_x. The numbers for 2002 are 2,102 tonnes for HC, 19,412 tonnes for CO and 1,405 tonnes of NO_x. These estimates are derived by taking the assumed emission rates of these vehicles multiplied by the expected mileage they would have been driven over the ensuing 12-month period.

The "removed from use" reductions are somewhat larger than those attributable to repairs. This is because the vehicles involved are assumed to have zero emissions after retirement, while repaired vehicles have a benefit equal to the difference in pre- and post-repair emission levels.

1.1.3 PRE-AIRCARE REPAIRS

Anecdotal reports from the public and the repair industry suggest that there is a certain amount of maintenance work that is performed on vehicles prior to AirCare inspections, with a view to avoiding the inconvenience of repairing and re-inspecting the vehicle in the event that it fails. Logically, this practice must exist but it has been difficult to quantify since the vehicles involved simply pass their initial inspection. In the absence of a program, it is likely that some portion of this preventative maintenance would not occur and would therefore result in increased fleet emissions. However, even if the program administrators were aware of the number and nature

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of pre-inspection repairs, it would be difficult to determine how many vehicles would have failed the emission test without pre-test repairs. Due to the uncertainty regarding this program effect, no attempt has been made to quantify the emission reductions attributable to it.

1.1.4 "With AirCare" Scenario Compared to "Without AirCare"

After ten years of operation, the cumulative effect of repairs made to excess-emitting vehicles has been significant. In every year, carryover benefits from previous cycles are apparent in that vehicles that failed one two or more years ago are still passing. In the absence of a program, it is quite likely that these vehicles would have continued to degrade from the point of failure, rather than being corrected and restored to normal emissions performance. These effects combined with accelerating the retirement of older, high-polluting vehicles has resulted in a significant emissions benefit. By comparing the actual vehicle-related emissions inventory for 2002 with the amount that would have occurred in the absence of AirCare testing, the indicated reduction is 35%.

1.2 AirCare II vs. AirCare I

As vehicle emission control technology has evolved, the task of identifying "excess-emitting" vehicles has become more difficult. Levels of emissions from malfunctioning current-technology vehicles may actually be lower than "as new" emission levels for vehicles built in the 1970s or early 1980s. In order to take full advantage of new emission control technologies, faults in newer vehicles must be detected and repaired as expeditiously as possible. The ability to distinguish between normal and abnormal emitters among new technology vehicles requires more rigorous test procedures. In order to maintain the effectiveness of the AirCare program in the period up to August 31, 2006, new measurement equipment was installed and new inspection procedures were implemented.

On January 2, 2001, many changes to the test regime became effective, most significantly the adoption of the IM240 transient emission test for all 1992 and newer vehicles. In conjunction with this change, the frequency of testing for these newer vehicles was reduced to biennial from annual. Annual testing was retained for 1991 and older vehicles.

The changes to the program were made to address known deficiencies in the 1992-2000 AirCare program and to keep pace with technological developments in the inspection industry. AirCare is the only I/M program to offer both ASM and IM240 testing in the same lanes and is likely the only program in the world using a transient dynamometer diesel opacity test. Cut points are strict with EPA final cut points being used for IM240 testing and AirCare-derived limits being used for ASM testing. With advanced testing methods, stringent cut points and a high rate of compliance, it must be concluded that the AirCare program is one of the most effective programs in existence in terms of identifying excess-emitting vehicles in the fleet.

The table below summarizes the key differences between AirCare II and the version that operated from 1992 to August 31, 2000 (AirCare I).

Differences Between AirCare II and AirCare I

	AirCare I	AirCare II
Test Procedures	ASM 2525/Idle Idle Tests for All-Wheel Drive Vehicles or Other Non-Testable Vehicles on Dynamometer Steady-state Diesel test (50 km/hr, 10.0 hp)	IM240 Test for 1992-and-newer vehicles ASM/Idle Test for 1991 and older All-Wheel Drive vehicles tested on 4WD dynamometers. Idle tests only for non-testable vehicles Transient driving cycle for diesel vehicles
Testing Frequency	Annual	1992 and newer – Biennial 1991 and older – Annual
Test Fee	$16.05 - $24	1992 and newer - $48 1991 and older - $24 1992+ Re-inspection - $24
Gas Cap Pressure Test	None	All 1972 – 1995 vehicles
On-Board Diagnostic Check	None	All 1998 and later vehicles
Visual Inspection	Gas Cap for all, Catalytic Converter on 1988 and newer vehicles, other underhood components advisory only for 1987 and older, mandatory for 1988 and newer	Gas Cap for all, Catalytic Converter on 1988 and newer vehicles. No underhood inspection
On-Line Repair Data Collection	None. Hard copy form only with 34 items.	Repair Net. Electronic repair information entry with 91 possible entries and comments field. On-line collection of oxygen sensor min/max voltage, response time and cross counts along with catalytic converter efficiency test results.
Data Collection	Two test types - "I" and "R". "R" applied only to vehicles with submitted Repair Data Form. Ad hoc reporting capability only for previous six months of data	Test counter indicates multiple tests. Counter re-sets with Pass or Conditional Pass. All test data since 1992 available at all times. Data queries and standard reports available on line as desired. Emission data collected on a second-by-second basis and graphs made available for failing vehicles on "Diagnostic Trace Report"
Wait Time Monitoring	Manual Only	Automated calculation of wait time with display on electronic sign at station entrance
Test Lane Monitoring	Audit Only	Electronic surveillance using video cameras
Calculation of Program Benefits	Separate laboratory test program for failing vehicles, yielding HOT 505 mass emission data before and after repairs. Approximately 375 vehicles per year tested.	Ongoing Sample Test program selecting a representative sample of 8000 full-duration IM240 tests per year on both passing and failing vehicles

1.3 INSPECTION STATISTICS

The next table summarizes the tailpipe emission and diesel opacity inspection data from 2001 and 2002.

The data suggest that the introduction of IM240 testing had a dramatic effect on the failure rate for newer vehicles. Prior to 2001, the failure rate for 1992-and-newer vehicles was less than 3%. In 2002, the failure rate for 1992-and-newer vehicles reached 9.6%. This was primarily due to high failure rates for 1992 model year vehicles and 1994 and 1995 model year trucks.

Differences Between AirCare II and AirCare I

	AirCare I	AirCare II
Test Procedures	ASM 2525/Idle Idle Tests for All-Wheel Drive Vehicles or Other Non-Testable Vehicles on Dynamometer Steady-state Diesel test (50 km/hr, 10.0 hp)	IM240 Test for 1992-and-newer vehicles ASM/Idle Test for 1991 and older All-Wheel Drive vehicles tested on 4WD dynamometers. Idle tests only for non-testable vehicles Transient driving cycle for diesel vehicles
Testing Frequency	Annual	1992 and newer – Biennial 1991 and older – Annual
Test Fee	$16.05 - $24	1992 and newer - $48 1991 and older - $24 1992+ Re-inspection - $24
Gas Cap Pressure Test	None	All 1972 – 1995 vehicles
On-Board Diagnostic Check	None	All 1998 and later vehicles
Visual Inspection	Gas Cap for all, Catalytic Converter on 1988 and newer vehicles, other underhood components advisory only for 1987 and older, mandatory for 1988 and newer	Gas Cap for all, Catalytic Converter on 1988 and newer vehicles. No underhood inspection
On-Line Repair Data Collection	None. Hard copy form only with 34 items.	Repair Net. Electronic repair information entry with 91 possible entries and comments field. On-line collection of oxygen sensor min/max voltage, response time and cross counts along with catalytic converter efficiency test results. Test counter indicates multiple tests. Counter re-sets with Pass or Conditional Pass.
Data Collection	Two test types - "I" and "R". "R" applied only to vehicles with submitted Repair Data Form. Ad hoc reporting capability only for previous six months of data	All test data since 1992 available at all times. Data queries and standard reports available on line as desired. Emission data collected on a second-by-second basis and graphs made available for failing vehicles on "Diagnostic Trace Report"
Wait Time Monitoring	Manual Only	Automated calculation of wait time with display on electronic sign at station entrance
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Summary of Inspection Data in 2001 and 2002

	2001	2002
Number of Inspections Performed	882,741	954,598
Number of Vehicles Inspected	748,068	778,521
Number of Vehicles Failed Initial Test for all Reasons Combined	114,189 (15.3%)	127,437 (16.37%)
Number of Vehicles Failed Initial Test for Emissions Only	93,468 (12.5%)	110,830 (14.2%)
Number of Vehicles Tested According to ASM/Idle Test	446,544	397,902
Number Failed ASM/Idle Test	78,295 (17.5%)	74,112 (18.6%)
Number of Vehicles Tested According to IM240 Test	283,777	359,974
Number Failed Initial IM240 Test	13,044 (4.6%)	34,419 (9.6%)
Number Failed Idle Test	595	1,198
Number of Diesel Vehicles Inspected	13,830	13,503
Number Failed Diesel Opacity Inspection	1,069 (7.7%)	760 (5.6%)
Number Failed Unloaded Diesel Opacity Inspection	1	0

The table below summarizes the results of the various non-tailpipe tests

Observations of Non-Tailpipe Tests

	2001	2002
Number of Gas Cap Pressure Tests Conducted	631,077	587,313
Number Failed Gas Cap Pressure Test	29,446 (4.67%)	23,237 (3.96%)
Number Failed Gas Cap Presence Test	1,342	1,410
Number of 1996 and Newer Vehicles Interrogated for OBD-II	60,470	145,988
Number Failed OBD- II Inspection	466 (0.77%)	2,039 (1.40%)
Number Failed Catalytic Converter Presence Test (1988 and Newer Only)	189	232
Number of Catalytic Converter Advisories (1987 and Older Only)	3,143	4,949

The gas cap pressure test failure rate ranged from 4% to 7% throughout the reporting period. A comparison of the failed vehicles from 2002 against the 2001 group resulted in very little indicated overlap between the two populations. There have been reports of brand new caps

failing the re-inspection, suggesting problems with some replacement caps. In some cases, multiple replacements have been found to be unable to pass the test. To a large degree, the automotive parts sellers have responded to the demand for replacement caps with products of the necessary quality.

1.4 Response to Failed Inspection

The table below shows the actions taken in response to failing inspections:

Observations on Actions Taken after Failing Inspections

	2001	2002
Number of Vehicles Not Returning for Re-inspection	22,604 (24.2%)	24,335 (22.0%)
Number of Vehicles Repaired to Pass by Certified AirCare Repair Facilities	21,295 (22.8%)	24,805 (22.4%)
Number of Vehicles Re-Inspected to Pass Without Repair Information	41,839 (44.8%)	52,432 (47.3%)
Number of Diesel Vehicles Passing Re-Inspection	738	543
Number of Gas Cap Replacements	Not Measured	19,212
Number of Vehicles Issued Conditional Pass	9,883 (10.6%)	11,469 (10.3%)

According to the data, approximately two thirds of the vehicles that satisfied the following three conditions:

1. failed for emissions,
2. returned for re-inspection,
3. passed re-inspection,

did not have any associated repair information. This suggests that they were repaired by a non-certified repair facility or possibly by a "Do-It-Yourself" amateur mechanic, but it is impossible to say for certain that repairs were actually performed in all cases. It is possible that some portion of this group would have attempted another test without repairs and managed to pass or made temporary repairs to secure a passing result. However, there are twice as many non-certified repair shops in the Vancouver area than certified shops and, since these facilities cannot qualify their customers for a Conditional Pass, they must repair vehicles to fully pass the inspection. We believe that the incidence of successful non-certified repairs greatly outnumbers the number of illegitimate passes. The ratio of certified repairs to non-certified repairs is consistent with the ratio of non-certified repair shops (approx. 900) to certified repair shops (approx. 450).

1.5 Effectiveness of Repairs

The only data available to evaluate the effectiveness of repairs comes from the certified repair industry. Unfortunately, as mentioned above, only 33% of failing vehicles have associated repair data returned to the program administrators. Furthermore, it is possible that the vehicles

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taken to certified repair shops are not representative of the overall failing-vehicle population. Owners of vehicles in poor condition may purposely seek out certified repair shops so as to take advantage of repair cost limits and continue driving their vehicle without having to fully repair it. Therefore, certified shops may deal with a higher proportion of vehicles that require costly repairs.

Nevertheless, the certified repair industry was able to successfully repair about 70% of the vehicles for which they submitted repair data. This effectiveness rate has been quite consistent since AirCare began in 1992. Analysis of repair data in two groups - 1992-and-newer vehicles and 1991-and-older vehicles - suggests that a slightly higher percentage of newer vehicles were not successfully repaired (33.5% in 2002), perhaps reflecting unfamiliarity of the repair industry with the IM240 test procedure. It is concerning to note that a high rate of Conditional Passes continues to exist for 1991-and-older vehicles (30.5% in 2002). These vehicles are tested according to the simpler ASM/Idle test that the repair industry has been exposed to for the past ten years. The increasing age and deteriorating condition of this older vehicle group may be the reason that the success rate of repairs has hit a plateau.

In 2001 and 2002, more than 50% of the Conditional Passes issued were "Q" waivers, meaning that the estimated cost of repair was less than the repair cost limit and no items were indicated as remaining defective. These cases may be characterized as misdiagnoses. For 1992-and-newer vehicles, the ratio of "Q" waivers to "C" waivers was greater than 2:1, suggesting that improper diagnosis, rather than the cost of repairs, was the limiting factor in achieving a full repair.

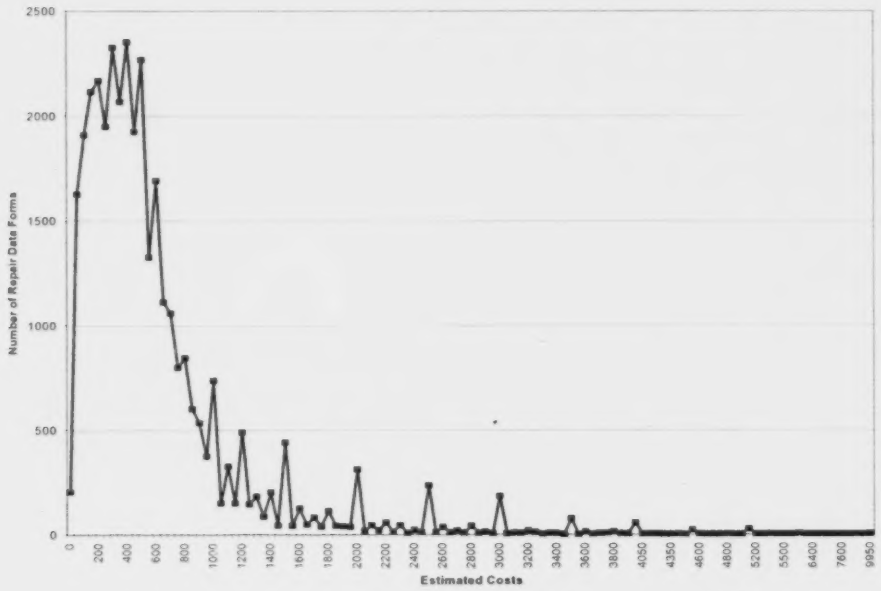
The most common repairs involved the replacement of the oxygen sensor, catalytic converter, spark plugs, air filter and EGR valve. In terms of adjustments, cleanings and other repairs, combustion chamber deposit removal and other chemical and physical cleaning actions were most prevalent. Ignition timing and idle mixture adjustments were common repair actions on older vehicles. Such adjustments are not possible on newer vehicles. Engine mechanical defects, low-efficiency catalytic converters and defective carburetors were the items most frequently mentioned as being required but not repaired, usually due to the cost involved.

The number of AirCare-certified repair facilities has declined slightly since 2000. The reasons for this are not known, but it is possible that the requirement to enter repair information through the Internet proved to be a disincentive for some shops. The number of AirCare-certified repair technicians has remained fairly stable at about 1200. Approximately 50% of technicians whose certification is expiring are automatically re-certified by virtue of having a Repair Effectiveness Index (REI) higher than the industry average in their last year of certification. Of technicians not eligible for automatic re-certification, the pass rate on the re-certification exam is approximately 60%. The remaining technicians must complete a training course and successfully pass the exam to retain their certification. A significant portion of the technicians in this position appear to let their certification lapse.

The AirCare administration office provides technical support to the repair industry through a telephone hotline. In 2002, 4795 calls were made to the hotline. It is believed that this technical support is critical in helping the repair industry deal with emission failures. Further support was provided to the industry through quarterly newsletters and a complete revision of the Repair Centre Manual which was posted on line at the AirCare web site.

1.5.1 COST OF REPAIRS

The average actual cost of repairs reported by certified AirCare repair facilities was $343 in 2001 and $377 in 2002. Performing a frequency distribution of the data suggests that a significant portion of repairs cost less than $200. Although certified repair centres frequently cite repair cost limits as a constraint on their ability to perform effective repairs, 85% of the time, the estimated cost of repair was less than the applicable repair cost limit. The figure below illustrates the frequency distribution of estimated repair costs from Repair Data Forms submitted in 2002.



Distribution of Estimated Repair Cost in 2002

The frequency distribution of estimated repair costs indicates that the median cost is $450. By comparison, 25 percentile is at $250 and the 75 percentile is at $701. The peaks on the above figure indicate the estimates were very often rounded up to multiples of $500, e.g. $1,500, $3,000 and so on.

1.6 SAMPLE TEST DATA

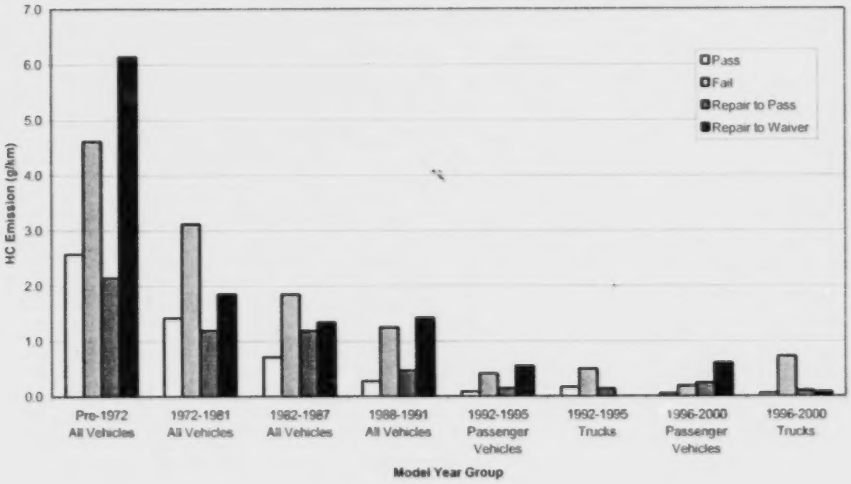
In simplest terms, the benefit of an inspection and maintenance program is equal to the difference in total vehicle emissions with an I/M program compared to the expected amount that would have occurred without it. In order to construct a model of fleet emissions, it is necessary to obtain mass emission data for all types and ages of vehicles in the fleet.

In March of 2001, a mass emission sampling test program was initiated with a target of 8,000 full-duration IM240 tests per year. The 8,000-vehicle sample was designed to include representative quantities of cars and trucks by age, type and manufacturer. In order to fulfil the requirements of the program, even vehicles normally subject to ASM/Idle tests were required to undergo full-duration IM240 testing.

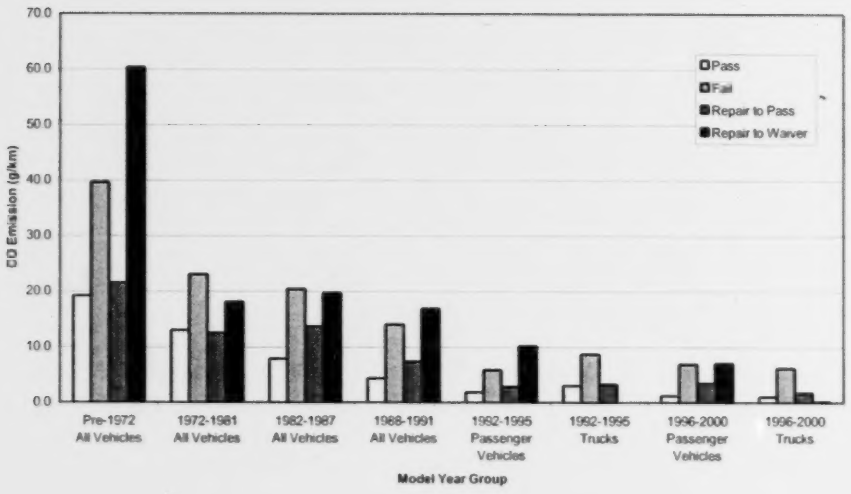
The program did not get fully underway until mid-2001 and, as a result, the sample size as of December 31, 2002 was limited to 8,872 initial tests. Of these, 7,986 were passes and 886 were fails. There were 766 after-repair tests recorded among the failed vehicle group. The data made available by the sample test program is extremely valuable in that it provides information on the passing portion of the fleet. In previous years, it was necessary to rely on a parallel testing program wherein HOT505 mass emission tests were performed on a voluntary sample of failing vehicles. This program was useful but was limited to about 400 vehicles per year and suffered from the fact that the participating vehicles were not necessarily representative of all failing vehicles because the owners volunteered to participate.

The sample group was divided into 8 sub-populations; all pre-1972 vehicles, all 1972-1981 vehicles, all 1982-1987 vehicles, all 1988-1991 vehicles, 1992-1995 cars, 1992-1995 trucks, 1996-2000 cars and 1996-2000 trucks.

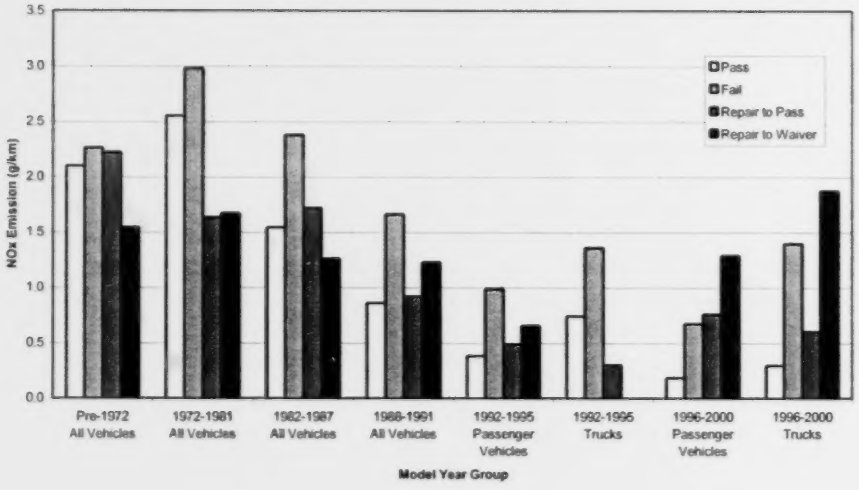
The figures below illustrate the comparison of passing, failing and post-repair emission rates for all 8 groups by emission.



HC Emission Factors by Model Year Group



CO Emission Factors by Model Year Group



NO_x Emission Factors by Model Year Group

The figures show clearly that older vehicles have much higher emission rates than newer ones.

They also confirm that the emission output of failing vehicles is much higher than corresponding passing vehicles and that the typical "repaired to pass" emission rate is much lower than the failing rate. In all but 4 cases, however, the average emission rate of a "repaired-to-pass"

vehicle is not quite as good as that of an "initial passing" vehicle. Hydrocarbon emissions from repaired 1981-and-older vehicles are better than initial-passing vehicles NO_x emissions from 1972-1981 vehicles are better after repair. Significantly, the post-repair NO_x emission levels for 1992-to-1995 trucks are considerably lower than those of initial-passing versions.

Aside from the above-mentioned exceptions, vehicles that have failed inspection and have been repaired do not achieve the same average emissions performance as their passed-first-time counterparts. This effect has been observed in other analyses of I/M programs. It suggests that repairs are sometimes incomplete or that there are non-reversible effects of some emission-related defects. For example, a misfire condition that causes a hydrocarbon emission failure can cause thermal damage to the catalytic converter. When the misfire is repaired, HC emissions will be reduced, but not to the extent that they would have occurred if the converter had not experienced collateral damage from the misfire.

Vehicles that received a Conditional Pass had much higher post-repair emission results than vehicles that passed. In some cases, Conditional Pass recipients had even worse results on average than they did before they were "repaired". For pre-1972 vehicles, Conditional Pass recipients had worse HC and CO emissions than the average failing vehicle. For the newest vehicles (1996-2000), post repair NO_x emissions tended to be worse than the average failing level. Conditional Pass recipients from this group had NO_x emissions many times higher than passing vehicles and considerably worse than failing vehicles. There were, however, only 550 1996 or newer vehicles that received a Conditional Pass.

1.7 Calculation of Program Benefits

The significant progress made by the automotive industry in lowering vehicle tailpipe emissions is evident in the way that the passing vehicle emission rates have declined significantly for the newer vehicles. The emission rates indicated in the figures represent hot-start, IM240 emissions and are therefore not completely representative of emission factors that would be used in emissions inventory modelling, but should provide a reasonable relative indication of the performance across age and technology groups.

The IM240 mass emission sample provides a sufficient number of passing, failing and re-inspected vehicles to derive emission factors with which percentage emission benefits due to repairs can be calculated. The basic approach involves choosing the most common failure modes within different groupings of vehicles and matching these modes to data in the mass emission sample. For example, it is assumed that all trucks from model years 1992-1995 that failed for excessive hydrocarbons and excessive NO_x would have the same emission rate as the matching failed and post-repair average emissions of all 1992-1995 trucks in the mass emissions sample.

Overall, for the 4 categories of vehicles subject to ASM/Idle testing, the top six failure modes were selected. Although 32 possible outcomes are possible, the top six modes accounted for 67% to 78% of all failures. For vehicles tested to the IM240, there are only 8 possible outcomes and therefore every one was considered. The overall matrix of before and after repair emission factors is too large to include in the summary, but there were sufficient examples in the mass emission sample to populate all the necessary fields.

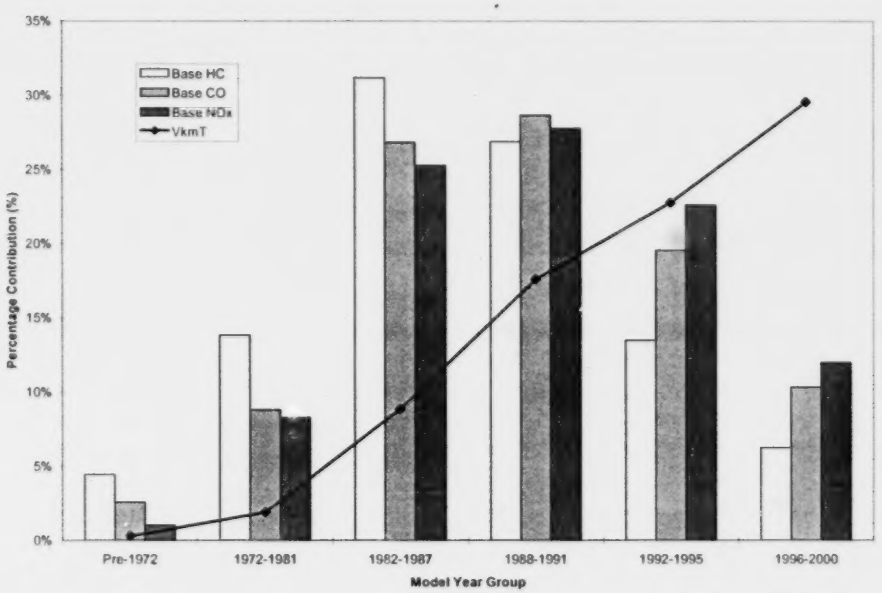
Using data on the number of vehicles in each group and their annual miles travelled, it was possible to compute the total grams of emissions generated by vehicles in each of the 8

categories for the baseline scenario with no repairs and for the post-repair case. The reductions attributable to repairs were then calculated as a percentage of the base case. A further estimate of the effect of the "disappeared" vehicles was calculated by assuming that the "Removed From Use After Failure" vehicles would have continued to operate at failing vehicle emission rates in the absence of a test program. This effect was calculated separately from the repair effect.

The mass emission rates from the IM240 testing are different from the factors used in inventory models like MOBILE 6, making it necessary to apply the calculated percentage reductions to the inventory results computed by MOBILE 6 in order to derive the tonnage of emission reductions that can be assigned to the program. Data were provided by the Greater Vancouver Regional District for calendar year 2000 and were calculated using the MOBILE 6 inventory model.

1.8 Contribution by Age Group to Overall Emissions

Using the IM240 emission factors from the 9,000-vehicle sample, it was possible to calculate the relative contributions of different age and technology groups on overall emissions. The chart below indicates that 1996 and newer vehicles, despite accounting for more than 30% of the total vehicle-kilometres-travelled (VkmT), accounted for only 8-12% of the total emissions generated. At the other extreme, 1972 and older vehicles accounted for only 0.6% of the VkmT but contributed almost 5% of all vehicle-generated HC emissions. In general, pre-1992 vehicles accounted for less than 50% of the VkmT, but produced 67%-76% of total emissions.



VkmT Vs. Emissions Contribution by Model Year Group

1.9 CONCLUSIONS

- The changes made to the AirCare program, in particular the move to IM240 testing, have significantly boosted the program's ability to identify excess-emitting vehicles with more than 200,000 test failures noted within the two-year review period.
- Non-certified repairs accounted for more than 100,000 successfully-re-inspected vehicles in the two calendar years combined, compared to 43,000 for the certified repair industry.
- More than 30% of repairs performed by certified repair shops were unsuccessful in achieving a passing re-inspection. In over half of these cases, it appears that misdiagnosis is the reason rather than limitations imposed by the repair cost limits.
- According to "Estimated Cost of Repair" data submitted by certified repair shops, 25% of vehicles brought as a result of failing AirCare required more than $750 of work to fully address all deficient items.
- Repairs to failing vehicles that resulted in a passing re-inspection showed a significant decrease in ASM and Idle emission readings for 1991-and-older vehicles and in IM240 emission results for 1992-and-newer vehicles. The Idle and ASM Space (ie, differences in ppm and % volumetric emission results for re-inspections compared to initial inspections) reductions associated with repairing a vehicle to pass are shown in the table below for calendar year 2002:

ASM/Idle Space Emission Reductions

Age Group	Idle HC	Idle CO	ASM HC	ASM CO	ASM NO_x
Pre-1972	61%	57%	52%	55%	3%
1972-1981	74%	64%	61%	66%	29%
1982-1987	73%	74%	57%	74%	40%
1988-1991	80%	92%	68%	87%	58%

- The IM240-space reductions for 1992-and-newer vehicles are shown in the Table below:

IM240-Space Emission Reductions

	HC	CO	NO_x
1992-1995 Cars	66%	61%	50%
1992-1995 Trucks	60%	57%	50%
1996+ Cars	72%	70%	57%
1996+ Trucks	67%	64%	56%

- The most common repairs were related to the replacement of catalytic converters and oxygen sensors, particularly for vehicles tested to the IM240 test. According to the repair data submitted, there were 5,779 catalytic converters replaced in 2001 and a further 10,678 in 2002. For oxygen sensors, there were 8,328 replacements in 2001 and

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an additional 11,803 in 2002. It should be kept in mind that these figures reflect only repairs for which repair data was submitted. If these repairs are representative of the overall failing vehicle population, the number of catalytic converters and oxygen sensors replaced as a result of the program would be triple these amounts.

- There continues to be a significant amount of spark plug and air filter replacements (7,304 and 5,008 respectively in 2002) associated with repairs to failed vehicles. These are basic maintenance items that are unlikely to be the main cause of an emissions failure. The high instance of these types of repairs suggests a continued misunderstanding of diagnostic and repair procedures by some repair facilities.
- Over 40,000 gas caps failed the functional pressure test in the review period. Confirmation of a successful gas cap re-inspection occurred in about 24,000 cases. No benefits from gas cap testing were calculated or included in this report.
- In calendar year 2002, interrogation of the OBD-II system on 1998-and-newer vehicles was successful in 143,146 cases. Of these, 2,039 (1.4%) were found to have the MIL commanded ON. Of these, 1,711 passed the IM240 test. The remaining 328 failed the IM240 as well as the OBD-II test. 2,865 vehicles failed the IM240 test (2.00%), but had no MIL illuminated. This effect is consistent with results observed in other programs. Of the 2,865 vehicles that failed the IM240 test, there were 899 repair data forms submitted, or 31% of all cases.

2.0 INTRODUCTION

This report provides an analysis of AirCare program operating statistics for the period January 1,2001 through December 31,2002. It is the first comprehensive report on the effectiveness of the program since the introduction of IM240 testing and other program changes on January 1, 2001. Although the contract between Translink and Envirotest Canada, the program operator, continues to define "program year" as the period from September 1st to August 31st, it was felt that a report based on two full *calendar* years would be more appropriate in light of the significant changes in test procedures and program policies implemented since the release of the "8-Year Report" in December of 2001. That report deviated from previous reporting practice by including test data up through December 31, 2000.

As of January 1, 2001, IM240 testing of 1992-and-newer vehicles on a biennial basis was introduced. In order to split the fleet, model years 1992, 1994, 1996, 1998, 2000 and 2001 were given a blanket exemption from AirCare testing in 2001, and were put over to 2002. Vehicles from model years 1993, 1995, 1997 and 1999 were required to be tested according to the IM240 test procedure and the vehicles that passed were given an AirCare Expiry date 726 days into the future from the date of inspection, meaning that they would not require an AirCare inspection prior to license renewal in 2002. The testing frequency for 1991 and older model years remained annual as in the previous program.

Effective January 1, 2002, the determination of the requirement for an AirCare test for any 1992 or newer vehicle was based on its previous AirCare Expiry Date. For the most part, 1993, 1995, 1997 1999, 2001 and 2002 model year vehicles were exempt from testing in 2002, however, there could be exceptions for any vehicle not tested in 2001. Vehicles tested to the IM240 test in 2001 that received only a Conditional Pass were also required to return for inspection in 2002. This change in program policy was intended to provide an incentive for vehicle owners to seek a full pass rather than accept a conditional pass.

This report also benefits from the availability of sample test data generated in the inspection lanes. By contract, 8,000 vehicles of all model years are to be tested each year to the full-duration IM240 test procedure with the intention of providing a representative sample of emission results for the overall fleet. These data allow for a better calculation of the emissions from passing vehicles, something that was lacking in previous analyses.

3.0 AIRCARE II VS. AIRCARE I

In addition to the changes described above, many other modifications were made to the AirCare inspection system, some as of September 5, 2000 and the others on January 1, 2001. These changes were as follows:

3.1 IM240 TRANSIENT TEST

From September 2, 1992 through December 31, 2000, the loaded test procedure used by AirCare was the ASM 2525, a steady-state test conducted at a constant speed of 40 km/hr and a fixed load corresponding to driving up a 3% grade. Although the ASM 2525 is an effective means of identifying excess-emitting vehicles, it does not require the engine or emission controls to prove their effectiveness under all conditions encountered in normal driving. To a large degree, the technological developments in emission controls since 1988 have been directed towards reducing emissions under cold-start and off-cycle transient operating conditions. Vehicles built to conform to U.S. EPA Tier 0 standards can pass an ASM 2525 test quite easily (normal ASM performance for a Tier 0 vehicle is 0-20 ppm HC, 0.00 – 0.05% CO and 100-500 ppm NO_x). Such vehicles need to be emitting considerably above their design specifications before they will fail. Making the pass/fail limits more stringent would address this to some degree but the possibility of wrongly failing vehicles increases as the standards are moved closer to zero. By testing modern vehicles according to a transient operating regime, the proper operation of the electronic engine management and the catalytic converter can be verified. Due to the fact that the test is more challenging, normal performance levels are further away from zero and give more scope for adjusting the stringency of the test without causing excessive false failures.

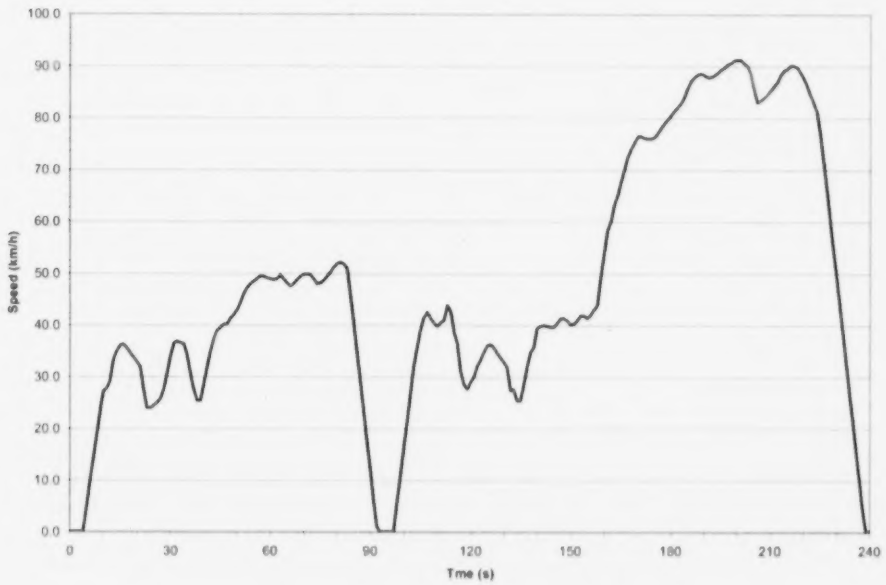

Figure 1. IM240 Driving Cycle

The IM240 prescribes a driving cycle divided into two phases as shown in Figure 1. The first, lasting 93 seconds, consists of an acceleration from rest to a low speed cruise followed by braking to an idle. The peak speed reached in this phase is 52.1km/hr and the average speed is 34.9 km/hr. After a brief idling period, a second driving phase, this one reaching a peak speed of 96 km/hr. The total distance covered is 3.152 km, at an average speed of 47.28 km/hr. The maximum acceleration rate is 5.31 km/hr per second, which equates to a 0-100km/hr time of 18.83 seconds.

Another significant difference between the IM240 test and the ASM test is that the IM240 measures the emissions in terms of mass per unit distance travelled. This is an important difference and serves to eliminate one of the weaknesses of the ASM test. In the ASM test, exhaust emissions are sampled on a volumetric basis. In other words, the analyzer draws in a portion of the exhaust gas and determines the concentration of each component of interest. What is missing from this method of measurement, however, is the volume of exhaust gas being produced. As a result, concentration-based measurements give only a partial picture of the emission output of a vehicle. In the IM240 test, all of the exhaust gas is collected and passed through a device called a Constant Volume Sampler. The sampler allows for simultaneous measurement of the volume of exhaust gas and the concentration of each pollutant of interest. Using a mathematical formula the cumulative mass of each emission can be measured and incremented once per second. Mass emission measurements are far more descriptive and correlate much better to the certification test used by new vehicle manufacturers. For this reason, auto manufacturers endorse the IM240. In much the same way that vehicles of a particular type are all subject to the same mass emission standard, IM240 testing prescribes one standard for all vehicles within a specific category of model year and type. For example, all 1993 model year cars would be tested to the same pass/fail limits, regardless of their weight, size or engine displacement. This greatly simplifies the process compared to the ASM test procedure, where applicable concentration limits must be adjusted to account for differences in vehicle weight and engine size.

Another useful feature of the IM240 test is that the dynamometer loading is much more representative of actual driving. On the ASM test, the vehicle operates at a constant speed and a resistant torque is applied to the wheels. Measuring the amount of torque applied and multiplying by the roll speed yields the horsepower value for the test. Typically, horsepower loadings range from 6.0 to 22.0 hp, which is normally only a small percentage of the total available power of the vehicle being tested. During urban driving, most of the energy expended by the engine is used in accelerating the mass of the vehicle to traffic speed from rest. Therefore an accurate simulation of actual road forces by a dynamometer must include the inertia weight of the vehicle. The other factors that determine the power requirement to sustain a particular driving pattern include tire rolling losses and aerodynamic drag. Tire rolling losses are present on the dynamometer due to the interaction of the tires and the dynamometer rollers. Aerodynamic drag forces can be simulated by applying the appropriate load for a given road speed. Aerodynamic force increases with the square of velocity, meaning that a second order equation must be used to describe the load vs. speed relationship. Ideally, the dynamometer will enable a precise simulation of actual road forces in a laboratory or test lane setting, allowing for the collection of exhaust emissions under representative driving conditions.

Although it would be preferable to perform the full, 240-second test on every vehicle to achieve maximum consistency and comparability of test results, the maximum throughput rate of the testing lanes would be severely limited compared to other, less sophisticated I/M test procedures. As a result, "fast-pass" provisions are designed into the test. A fast-pass allows for the termination of the test after as little as 30 seconds if the emissions measured to that point

are sufficiently low to predict an overall passing result if the test were to proceed to completion. In order to develop the fast-pass criteria, researchers working for the U.S. EPA analysed a large sample of data from full-duration IM240 tests.

As the IM240 test is being performed, the cumulative grams of HC, CO and NO_x are calculated once per second and compared to a table of fast-pass criteria. If, at any point after 30 seconds, all three values are simultaneously below the established fast-pass criteria, the vehicle fast-passes.

There are a number of ways to pass an IM240 test. There are fast-pass criteria for the full test, and for Phase 2 only. If a vehicle does not achieve a fast pass in either mode, it will complete the full 240-second test. At this point, the total grams of each pollutant will be divided by the actual distance travelled, producing what is called a "Composite" result. If this value exceeds the pass/fail limit, a secondary calculation is performed, using only the mass of emissions and distance travelled in Phase 2 of the test. These Phase 2 results are compared to a set of "Phase 2 Standards" and, if the calculated Phase 2 emissions are lower than the applicable standards, the vehicle is deemed to have passed the test. The Phase 2 provision allows the results of Phase 1 to be ignored if the vehicle is significantly cleaner in Phase 2. This type of behaviour is indicative of a vehicle where the catalytic converter might have cooled excessively while waiting for the test to be performed. In such cases, it would be improper to fail the vehicle as the catalytic converter may not be defective.

The only means by which a vehicle can fail an IM240 test is by completing the full test and not invoking any of the multiple ways of passing. A failing IM240 result is a composite result, based on the total mass of each pollutant and the distance of the full cycle.

Of all the available emissions short tests, the IM240 test is the most representative of the EPA 75 certification test that must be met by all light-duty vehicles. Therefore, it provides the most comprehensive method of checking whether a vehicle is still in compliance with its design standards, which is the ultimate objective of any in-use emissions inspection process.

One of the reasons that IM240 tests tend to be performed on a biennial, rather, than an annual basis, relates to the amount of time needed to complete the test. By definition, the IM240 test takes four minutes to complete, thus the theoretical maximum throughput rate is 15 vehicles per hour. Adding in vehicle set-up and tear-down time of one to two minutes on either side of the test, the maximum expected vehicle throughput rate drops to 10 or less. The throughput rate at AirCare inspection centres prior to 2001 tended to hover around the 13-15 vehicles per lane per hour. Even with the drop in required inspection volumes attributable to biennial testing, a higher throughput rate is needed for IM240 tests. In order to improve the throughput rate, there are fast-pass provisions built into the IM240 test to allow clean vehicles to stop as early as 30 seconds into the test. This results in a comparable situation to the ASM 2525 test, which also has fast-pass provisions to allow termination of testing as early as 30 seconds.

For vehicles that fail the test, the test cycle runs to the maximum for both the IM240 and the ASM. In the case of the ASM, the maximum mode length is 90 seconds, much shorter than the IM240. As a result of the longer period of time necessary to prepare vehicles for IM240 testing, the need to repeat the test if the driving cycle does not comply with acceptance criteria (the likelihood of which is increased by the transient nature of the test cycle), and other factors, the throughput rate at AirCare inspection centres dropped to about 10 vehicles per lane per hour from the previous 13-15. This reduction in throughput rate means that the drop in required

inspection volumes does not result in a reduction in the number of testing lanes or testing hours required.

3.2 TRANSIENT DIESEL TEST (D147)

In AirCare I, all diesel vehicles were tested according to a steady-state dynamometer test at 50 km/hr with a constant load of 10.0 hp. This test was developed and used by the Arizona I/M program in the 1980s and was adopted without change as the AirCare procedure. Exhaust gases were not analyzed – instead, the opacity level of the smoke produced was assessed using a smoke meter. The reason for this is that the exhaust from diesel vehicles contains particulate matter that must be filtered out before it can be passed through a gas analyzer. Due to the amount of particulate matter produced by some vehicles, the filter system would require frequent maintenance and would lead to unacceptable amounts of down time in the inspection lanes.

Diesel engines do not have a throttle valve, meaning that a large amount of excess air is present under all but maximum load conditions. This characteristic results in low emission readings on a volumetric concentration basis when compared to a spark ignition engine. Of the three regulated gaseous pollutants, diesel engines produce only NO_x in significant quantities. Measurement on a mass basis is essential to obtain an accurate picture of the emissions output of a diesel. This is possible, but the particulate matter in diesel exhaust also poses a problem for the constant volume sampler as well. Smoke opacity is a convenient way of identifying diesel-powered vehicles that have not been properly maintained or that have been tampered with. The smoke measurement method does not require that any sensitive analytical equipment be exposed to the diesel soot. The smoke measurement is indicative of the particulate emission rate, but does not allow a quantitative assessment of the amount of PM being produced. In general, diesel engines that have high measured opacity have high particulate emission rates, but a correlation factor has not been established to permit conversion from opacity to particulate emissions.

Over the years, it became apparent that the low-load, steady state test procedure was inadequate for testing diesel vehicles. The failure rate was very low and even vehicles that smoked objectionably when driven on the street were able to pass the test easily.

With the introduction of IM240 testing, and the upgrade to dynamometers with inertia simulation capability, it became possible to test diesel-powered vehicles under transient operating conditions. This was a significant step forward from the previous test, because diesel engines that are malfunctioning in some way tend to emit excessive amounts of smoke when the engine is operating under heavy load. Acceleration against an inertia weight is an effective way of loading the engine sufficiently to induce excess smoke.

The second phase of the IM240 test was adopted as the diesel test cycle. The name D147 was selected for this test because the second phase of the IM240 test is 147 seconds in length and the "D" designation was selected to denote a diesel test.

The smoke opacity is monitored continuously throughout the test and recorded once per second. The peak opacity reading is compared to the pass/fail standard. A correction factor based on the Beer-Lambert law is used to correct the measured opacity readings for vehicles of various engine sizes. In simple terms, vehicles with smaller, low-horsepower engines are allowed to produce more opacity than larger, higher-horsepower diesels. As a result of using

the Beer-Lambert equation, a universal standard of 30% is used for all diesel vehicles. Therefore, any peak that exceeds 30% is flagged as a failure. This procedure was further modified after initial trials with a secondary averaging feature. This was introduced to avoid failing vehicles that exceed the 30% limit for only a second or two during the test. Driver technique could be responsible for such momentary exceedances of the standard. In order to compensate for this and to ensure that failing vehicles have bona-fide emission-related defects, a second test result is calculated using the opacity readings for the three seconds prior to the peak and the three seconds after the peak. A new result is calculated using the seven-second average. If this value is less than 20%, the peak value is ignored and the seven-second average is reported as the test result.

The ability of the D147 test procedure to mimic actual driving conditions has resulted in a test procedure that is much more capable of identifying those vehicles that would be observed to be smoking objectionably in daily traffic. Anecdotal feedback from repair shops that specialize in diesel-powered vehicles suggests that the failing vehicles do have identifiable faults that, once repaired, significantly reduce the smoke output.

3.3 FOUR-WHEEL-DRIVE DYNAMOMETERS

Certain vehicles cannot be tested on a two-wheel-drive dynamometer because they are equipped with traction control or all-wheel-drive. Traction control senses speed difference between the driven and non-driven wheels and axles of a vehicle and applies braking torque or cuts engine power to minimize wheel spin. If a vehicle is operated on a two-wheel drive dynamometer, the non-driven wheels remain stationary, causing the traction control system to intervene when the driven wheels start turning on the dynamometer rollers. Some vehicles provide the ability to disable the traction control system and can thus be tested. Others cannot be disabled.

All-wheel-drive systems also sense speed differences between axles or between wheels and re-direct power to the wheel or axle with the greatest available traction. As in the case of traction control, operating such a vehicle on a two-wheel-drive dynamometer causes the AWD system to transfer torque from the spinning wheels to the stationary wheels. However, as the vehicle is restrained from moving, the transfer case can be damaged if an all-wheel-drive vehicle is driven on a 2WD dynamometer.

Given that all-wheel-drive and traction control are becoming more common in vehicles, particularly in light-trucks and sport utility vehicles, it was necessary to provide a number of 4WD dynamometers for AirCare II. Sixteen units were purchased for the network, enough to provide one unit in every inspection centre and two units in stations with a greater volume of newer vehicles.

The 4WD dynamometers are equipped with an additional set of rollers that can be moved to accommodate different wheelbases of vehicles. The front and rear roll sets are connected with a toothed belt so that both axles of the vehicle being tested rotate at the same speed. The loading applied by the dynamometer is automatically adjusted to compensate for the fact that there are twice as many tire/roller contact patches and greater parasitic frictional losses in the dynamometer mechanism. All of the 4WD dynamometers can operate as 2WD dynamometers simply by de-clutching the drive belt to the rear roll set. In this mode, the 4WD dynamometer becomes effectively identical to the 2WD version. Calibrations are performed in both modes to

correctly calculate parasitic losses and to apply the appropriate corrections in either operating mode.

The provision of 4WD dynamometers has allowed for loaded testing of certain vehicles such as Jeeps and Subaru vehicles that were exempt from loaded testing prior to September of 2000.

3.4 OBD-II TESTING

The move to three-way catalytic converters and closed-loop fuel control to meet the U.S. 1981 Tier 0 emission standards required that computers be used to interpret engine sensor readings and control the amount of fuel admitted to the engine in order to maintain the proper operating regime for the three-way catalytic converter. Over time, the capacity of on-board computers on vehicles has increased significantly and more and many vehicle systems now involve computer control (engine, brakes, transmission, etc.). To assist technicians with the diagnosis and repair of emission-related systems, diagnostic monitors have been built into the on-board computers to identify any problems with inputs and response to outputs. The first-generation on-board diagnostic systems tended to be manufacturer-specific with unique types of connectors, communication protocols and sensed parameters. Scan tools were developed to allow repair technicians to observe data stream information from the engine and to access diagnostic trouble codes, however, these scan tools were frequently dedicated to one brand of vehicle. In order to interrogate OBD systems on a wide range of makes and models of vehicles using a universal scan tool, it was necessary to have a multitude of adaptors and plug-in software modules that would have to be upgraded or expanded with each new model year.

In the early 1990's the automobile manufacturers and government worked together to address some of the problems with first-generation OBD systems. The result was a concept called OBD-II. This system uses only one type of connector and uses a universal core set of diagnostic trouble codes, thus allowing one scan tool to be used on all types of vehicles. In the United States, all light duty vehicles were required to be equipped with OBD-II systems as of the 1996 model year. In model years 1994 and 1995, 40% and 80% of vehicles were required to comply. Since vehicles sold in Canada tend to be configured identically to those sold in the U.S., there have been OBD-II systems operating in the Canadian fleet since 1994. However, it was not mandatory for vehicles sold in Canada to be so equipped until 1998. Certain manufacturers, such as General Motors of Canada, modified the OBD-II systems on some high-sales models sold in Canada due to concerns over Canadian fuel specifications. Canada allows the use of a manganese-based octane enhancer known as MMT. It is used in most Canadian gasoline at a usage rate of about 9 mg/L. Although MMT is allowed in the United States as well, it is not allowed in reformulated gasoline that accounts for a large share of the U.S. gasoline market. As a result, it is not widely used in the United States. General Motors of Canada was concerned that the Malfunction Indicator Lamp (MIL) might tend to illuminate incorrectly when MMT-containing fuel was used, causing undue customer concerns. In some cases, certain hardware configurations were deleted from Canadian vehicles or the software configured so as to store trouble codes but not illuminate the MIL. Due to the fact that universal compliance with OBD-II was not achieved in Canada until 1998, AirCare collects OBD-II information only on 1998 and newer vehicles. Since 1998, Canadian vehicles have been fitted with fully-compliant OBD-II systems, regardless of the presence of MMT in fuel.

At present, the information collected from the OBD-II interrogation is stored for analysis and has no bearing on the outcome of the test. In the United States, the U.S. EPA is moving towards the replacement of tailpipe testing with OBD-II interrogation. This change has already occurred

or is planned to occur in the majority of U.S. I/M programs. EPA has taken a strong position on this issue and does not support the use of tailpipe tests for vehicles equipped with OBD-II systems.

A number of studies have been carried out to assess the effectiveness of OBD-II in identifying vehicles with high emissions. In general, these studies have found that OBD-II was able to identify defects before tailpipe emissions exceeded federal standards. In some cases, vehicles will fail an IM240 test even though the OBD-II system is not detecting any faults. In many of these cases, subjecting the vehicle to a full FTP emission test confirmed that the vehicle was in compliance and that the IM240 failure was spurious.

More information on OBD-II will be presented later in this report.

3.5 GAS CAP PRESSURE TESTING

In addition to tailpipe emissions, motor vehicles produce evaporative emissions. Gasoline is a volatile substance and gasoline vapour forms readily in the vapour space above the liquid fuel in a vehicle's gas tank. These vapours, if allowed to escape, contribute to the total emissions of the smog-forming pollutants known as Volatile Organic Compounds, or VOC's. Prior to the advent of evaporative emission controls on automobiles in 1971, gasoline vapours were simply vented to atmosphere through a vent in the gas cap. In addition, vehicles with carburettors (and virtually every vehicle had a carburettor in those days) had a small reservoir of fuel in the float bowl, also vented to atmosphere.

The engineering solution to this problem was to install a charcoal canister and to connect vapour lines from the fuel tank and carburettor to the canister. Fuel vapours were adsorbed onto the surface of activated charcoal inside the canister, thereby storing them. Once the vehicle engine was running and at normal operating temperature, the stored fuel vapours could be purged by drawing air through the canister and into the intake manifold of the engine. The gasoline vapours would therefore be burned and the by-products of this combustion treated by the emission controls on the vehicle.

Evaporative emission control systems are passive in nature, having few active components. Due to the fact that the tank is now vented through the charcoal canister, the fuel cap must be sealed to prevent the escape of gasoline vapours. However, the system must be fitted with some form of vacuum and pressure relief, as air must be allowed to enter the tank as the fuel volume is used up and, in hot weather, excess pressure in the fuel tank must be relieved before damage can occur to the tank itself. The fuel cap typically performs these two functions using internal valves, although external systems are used in some vehicles.

Should the fuel cap not seal the tank, vapours will simply escape to atmosphere, rather than being trapped in the charcoal canister. Also, a malfunction in the canister purge operation will result in the charcoal canister becoming saturated with gasoline fumes, rendering the system ineffective.

In the early 1990's the U.S. EPA devised two tests to determine if the evaporative emission control test. One was a pressure test and the other was a purge test. The pressure test was done by introducing nitrogen under pressure through the tank vapour line at the charcoal canister end. Any loss of pressure would indicate a leak. The purge test was to be performed by cutting the purge line to the canister and inserting a flow meter. When the vehicle was being

tested, conditions would be right to support canister purging, thus there should be flow indicated in the purge line. Although well designed, these two tests proved difficult to implement in practice. In many cases, proper identification of the vapour and purge hoses was difficult-to-impossible. In many vehicles, the charcoal canister is not visible in the engine compartment, and the lines attaching to it may not be accessible. Indiscriminately cutting hoses under the hood of vehicles is potentially dangerous, so correct identification is essential. In pilot testing, it was discovered that purge failures were quite rare and that most cases of indicated tank leakage, the source of the leakage was at the gas cap. Therefore, the suggestion was made that testing only the gas cap would provide much of the emission reductions anticipated for the pressure/purge test, without the problem of having to physically handle hardware under the hood.

With the introduction of OBD-II, the monitoring of tank pressure and canister purge flow was included in the list of items to be checked by the on-board computer. Using solenoids, natural pressure or vacuum in the tank, or even an external pump, the on-board computer can detect a leak situation and advise the vehicle owner. Purge flow is monitored with a flow meter that is sensed by the computer. Lack of purge flow when the computer has enabled the system will indicate a fault code and illuminate the "Check Engine" light. Removal of the gas cap with the engine running on an OBD-II-equipped vehicle may trigger the MIL and store a Diagnostic Trouble Code (DTC). It is for this reason that AirCare testing requires gas cap testing only up to the 1995 model year. Since all U.S.-spec vehicles were fitted with OBD-II systems by 1996, it is reasonable to assume that all 1996 model year Canadian vehicles were equipped with OBD-II systems of some sort. However, because the systems were not legally required until 1998, the decision was made to forego testing of 1996 and 1997 model year vehicles by either method.

4.0 ANALYSIS OF AIRCARE INSPECTION DATA

4.1 FLEET PROFILE

Each year, a certain number of new vehicles are added to the fleet while a certain number of older vehicles are scrapped. The observed trend is that the number of vehicles removed from use is less than the number of new additions, resulting in a net positive growth in vehicle population each year. In previous years, estimates of the vehicle population were based entirely on inspection data. In other words, a vehicle that did not appear for AirCare testing was not counted as part of the vehicle fleet. In the past year, the Insurance Corporation of British Columbia (ICBC) has provided PVTT staff with registration data, indicating the number of vehicles actually licensed for road use. Figure 2 illustrates the distribution of vehicle model years for the AirCare-inspected fleet up to the end of 2002, compared with the ICBC registration data as of January 2003.

Looking at Figure 2, it is clear that there is a high degree of correlation between the number of vehicles licensed in ICBC Rating Territories D, E, and H (the AirCare catchment area) and the number of vehicles actually inspected. This confirms that the link between the AirCare inspection process and the vehicle licensing system is very effective in ensuring that the vehicles operating in the region are actually inspected as required. The only significant discrepancy between licensed and tested vehicles occurs in the pre-1979 group, where many vehicles are exempt due to Collector or Vintage licensing designations.

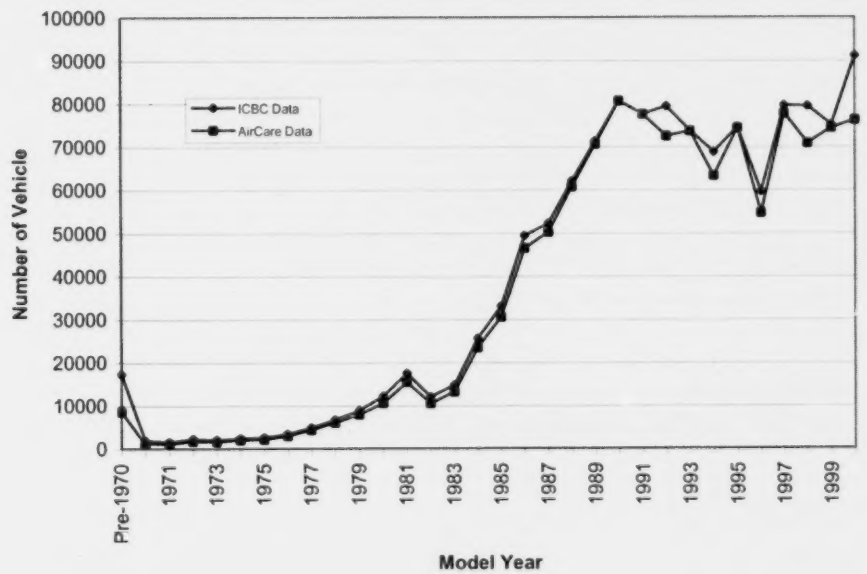

Figure 2. ICBC Licensed Vehicles vs. AirCare Inspected Vehicles by Model Year in 2002

As mentioned earlier, the fleet tends to grow from the addition of newly manufactured vehicles at a greater rate than the retirement of older vehicles. In previous years, it has been assumed

that about 50,000 older vehicles are removed from use annually. This figure should be reflected in the total number of 1991-and-older vehicles inspected in 2002 vs. 2001.

According to program data, the number of 1991-and-older vehicles tested in 2001 was 457,181. In 2002, the corresponding figure was 407,865. The loss of 49,316 units is close to what was anticipated.

With regard to newer vehicles, there were 77,307 model year 2000 vehicles inspected for the first time in 2002. This represents a higher number for any single model year since 1992 and reflects a surge in new-vehicle sales that has been prevalent in North America for the past few years. Large volumes of 2001 and 2002 vehicles are expected to become eligible once their new-vehicle exemptions expire in 2003 and 2004, respectively. According to January 2003 ICBC registration data, the number of 2001 model year vehicles is 78,000 and the number of 2002 vehicles is 97,000. These numbers will not necessarily translate directly into AirCare inspections, but the figures provide an indication of a recent expansion in the size of the fleet at a rate beyond anything seen in the 1990's.

4.1.1 MODEL YEAR DISTRIBUTION

Figure 3 and Figure 4 show the number of vehicles inspected by model year and vehicle type in years 2001 and 2002. The effect of the biennial exemptions can be seen clearly in that the "off-cycle" years indicate much lower test volumes than the "on-cycle" years.

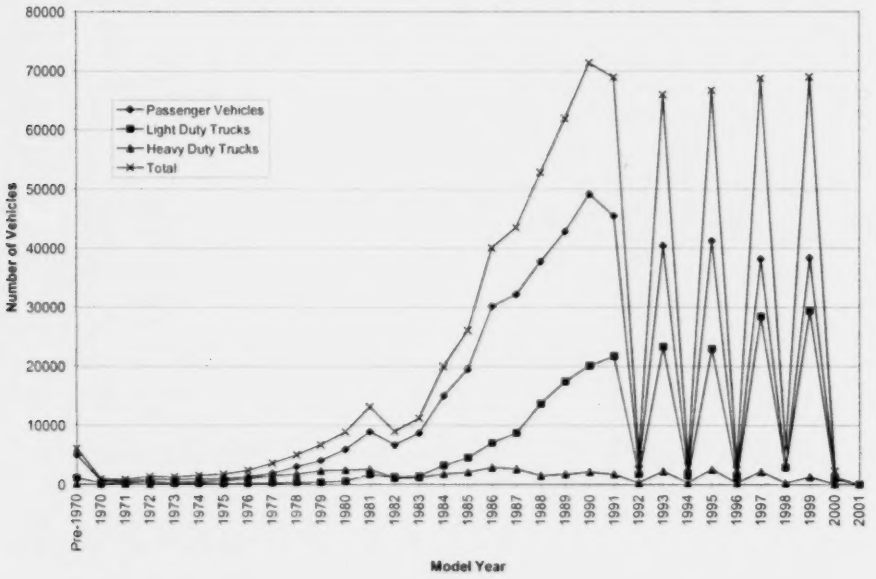

Figure 3. Number of Vehicles Inspected in 2001 by Model Year

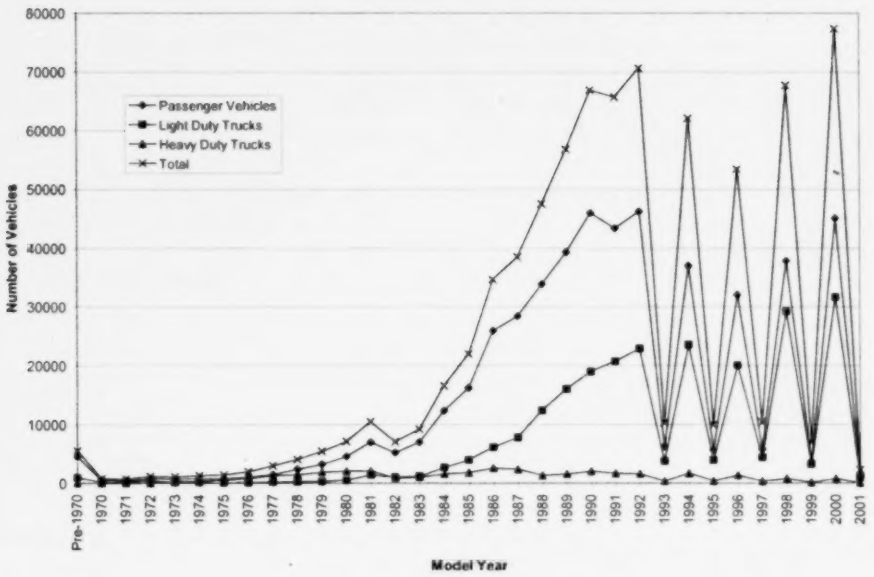

Figure 4. Number of Vehicles Inspected in 2002 by Model Year

4.1.2 ESTIMATED INSPECTION VOLUMES

Prior to the introduction of biennial testing, predictions were made of the volume of inspections to be performed each year. The number of inspections to be performed in calendar year 2001 was estimated by adding the known number of 1993, 1995, 1997 and 1999 vehicles in the fleet to the total number of 1991-and-older vehicles. The failure rate was predicted to be 6% among the newer age group and 25% among the older age group. This predicted inspection volume turned out to be quite accurate, 857,486 inspections compared to 808,094 predicted inspections. The prediction for 2002 was performed in a similar fashion, using the number of 1992, 1994, 1996, 1998 and 2000 model year vehicles in the fleet. Again, the failure rate for the newer vehicles was assumed to be 6% and the failure rate of the older vehicles was expected to be 25%. However, for 2002, the estimate turned out to be incorrect. Table 1 below shows the estimated volumes for both 2001 and 2002 compared to the actual test volumes:

Table 1. Projected and Actual Inspections in 2001 and 2002

Calendar Year	Projected Volume	Actual Volume
2001	808,094	857,486
2002	781,182	918,228

In order to determine the reason for the discrepancy between predicted and actual inspection volumes in 2002, the following factors were identified as contributors to higher volumes:

- The failure rate has been higher than expected in the 1992-and-newer vehicle group in 2002. The reasons for this are not absolutely clear. AirCare staff were directed to make

the pass/fail limits for light trucks and sport utility vehicles "as tight as technically feasible". In response to this direction, the EPA standards for these vehicles were tightened slightly and vehicles from 1994 and 1995 model years were combined with those of later years. As a result, 1994 and 1995 model year trucks were required to comply with the same standards as1996 model year trucks.

- Higher-than-expected volumes of 1991 and older vehicles, and 1992, 1994, 1996, 1998, 2000 model year vehicles. This, combined with the higher failure rate, contributed a significant number of additional inspections in 2002.

- Off-cycle vehicles being tested despite not requiring one. In 2002 most vehicles from model years 1993, 1995, 1997, and 1999 were not required to be inspected, but a significant number were. It is suspected that re-sale transactions may be responsible for this in that prospective buyers wish to have a recent AirCare pass on any vehicle they are considering buying. Although precise figures aren't available, ICBC has estimated that 17-20% of vehicles change hands each year.

- It has been observed that a proportion of failing vehicles have more than one failure prior to being repaired to pass. These multiple, yet unsuccessful, attempts to obtain a passing inspection result add to the total number of inspections being performed. In calendar year 2002, there were 23,691 vehicles that were tested three or more times in total. Overall, these multiple tests accounted for 35,874 additional inspections. The greatest number of consecutive tests for one vehicle was 18.

4.1.3 Growth in Truck Population

Table 2 shows the numbers of vehicles inspected by vehicle type in both 2001 and 2002. It can be seen that the fraction of the fleet comprised of light-duty and heavy-duty trucks is growing and now accounts for more than 35% of the AirCare fleet.

Table 2. Number of Vehicles Inspected by Vehicle Type in 2001 and 2002

	Total Number of Vehicles Inspected	
Vehicle Type	**2001**	**2002**
Passenger Vehicles	490,729	505,327
Light-Duty Trucks	216,993	238,851
Heavy-Duty Trucks	40,346	34,343

4.1.4 Distribution by Make

Figure 5 through Figure 7 show the distribution by make of 1991-and-older vehicles by vehicle type in 2001. Figure 8 through Figure 10 show the same distribution by vehicle type for 1992-and-newer vehicles. For calendar year 2002, Figure 11 through Figure 13 show the same distribution of makes for 1991-and-older vehicles. Figure 14 to Figure 16 show the corresponding distribution of1992-and-newer vehicles.

the pass/fail limits for light trucks and sport utility vehicles "as tight as technically feasible". In response to this direction, the EPA standards for these vehicles were tightened slightly and vehicles from 1994 and 1995 model years were combined with those of later years. As a result, 1994 and 1995 model year trucks were required to comply with the same standards as1996 model year trucks.

- Higher-than-expected volumes of 1991 and older vehicles, and 1992, 1994, 1996, 1998, 2000 model year vehicles. This, combined with the higher failure rate, contributed a significant number of additional inspections in 2002.

- Off-cycle vehicles being tested despite not requiring one. In 2002 most vehicles from model years 1993, 1995, 1997, and 1999 were not required to be inspected, but a significant number were. It is suspected that re-sale transactions may be responsible for this in that prospective buyers wish to have a recent AirCare pass on any vehicle they are considering buying. Although precise figures aren't available, ICBC has estimated that 17-20% of vehicles change hands each year.

- It has been observed that a proportion of failing vehicles have more than one failure prior to being repaired to pass. These multiple, yet unsuccessful, attempts to obtain a passing inspection result add to the total number of inspections being performed. In calendar year 2002, there were 23,691 vehicles that were tested three or more times in total. Overall, these multiple tests accounted for 35,874 additional inspections. The greatest number of consecutive tests for one vehicle was 18.

4.1.3 Growth in Truck Population

Table 2 shows the numbers of vehicles inspected by vehicle type in both 2001 and 2002. It can be seen that the fraction of the fleet comprised of light-duty and heavy-duty trucks is growing and now accounts for more than 35% of the AirCare fleet.

Table 2. Number of Vehicles Inspected by Vehicle Type in 2001 and 2002

	Total Number of Vehicles Inspected	
Vehicle Type	2001	2002
Passenger Vehicles	490,729	505,327
Light-Duty Trucks	216,993	238,851
Heavy-Duty Trucks	40,346	34,343

4.1.4 Distribution by Make

Figure 5 through Figure 7 show the distribution by make of 1991-and-older vehicles by vehicle type in 2001. Figure 8 through Figure 10 show the same distribution by vehicle type for 1992-and-newer vehicles. For calendar year 2002, Figure 11 through Figure 13 show the same distribution of makes for 1991-and-older vehicles. Figure 14 to Figure 16 show the corresponding distribution of1992-and-newer vehicles.

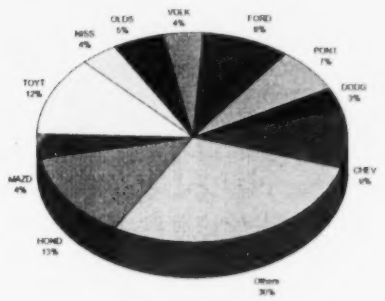

Figure 5. Distribution of Makes of 1991 and Older Model Year Passenger Vehicles in 2001

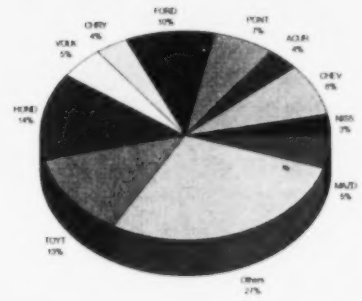

Figure 8. Distribution of Makes of 1992 and Newer Model Year Passenger Vehicles in 2001

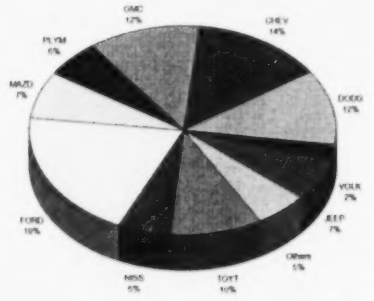

Figure 6. Distribution of Makes of 1991 and Older Mode l Year Light-Duty Trucks in 2001

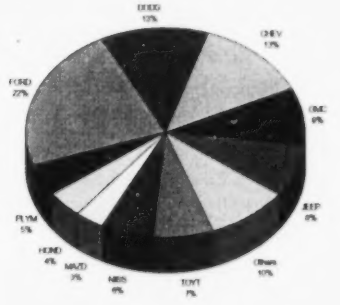

Figure 9. Distribution of Makes of 1992 and Newer Model Year Light-Duty Trucks in 2001

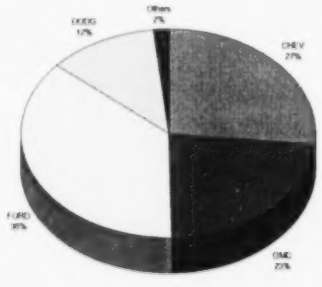

Figure 7. Distribution of Makes of 1991 and Older Model Year Heavy-Duty Trucks in 2001

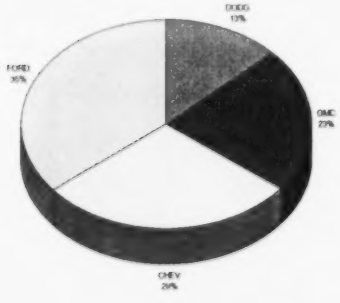

Figure 10. Distribution of Makes of 1992 and Newer Model Year Heavy-Duty Trucks in 2001

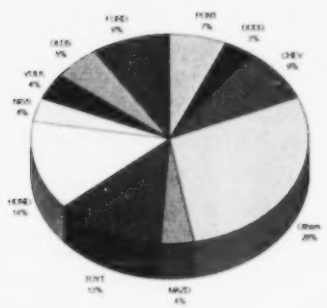

Figure 11. Distribution of Makes of 1991 and Older Model Year Passenger Vehicles in 2002

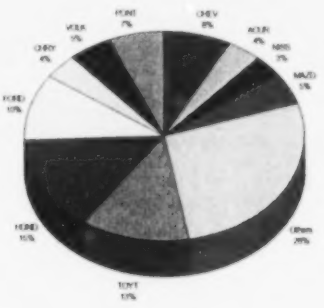

Figure 14. Distribution of Makes of 1992 and Newer Model Year Passenger Vehicles in 2002

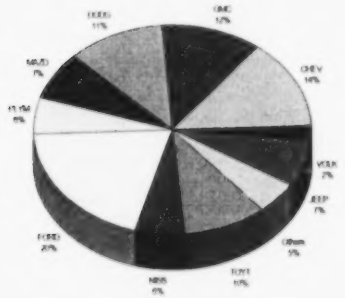

Figure 12. Distribution of Makes of 1991 and Older Model Year Light-Duty Trucks in 2002

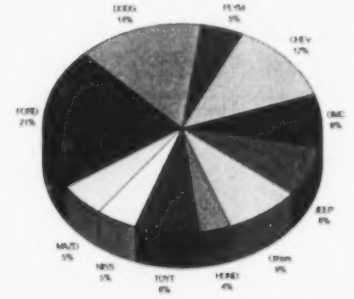

Figure 15. Distribution of Makes of 1992 and Newer Model Year Light-Duty Trucks in 2002

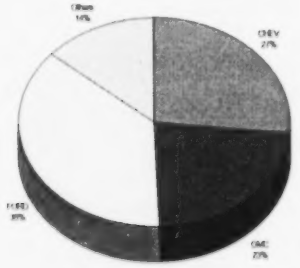

Figure 13. Distribution of Makes of 1991 and Older Model Year Heavy-Duty Trucks in 2002

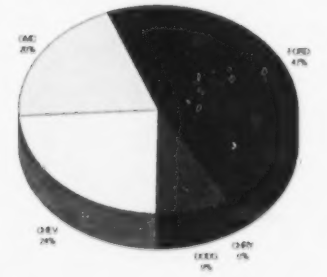

Figure 16. Distribution of Makes of 1992 and Newer Model Year Heavy-Duty Trucks in 2002

The above charts show that, for passenger cars, GM, Ford, Chrysler, Honda and Toyota account for over 60% of all vehicles inspected. In fact, the top 3 makes for both 1991-and-older, and 1992-and-newer passenger vehicles remained the same in 2001 and 2002. They are Honda, Toyota and Ford, which made up over 35% of all passenger vehicles in the AirCare fleet. For light-duty trucks, the representation by the "Big Three" domestic brands is much greater at more than 70%. However, the import brands are starting to make gains. For model 1992-and-newer light-duty trucks, imports currently make up more than 20% of the population. However, in heavy-duty trucks, there is little representation from any manufacturer other than GM, Ford or Chrysler who combine to account for 99% of the market.

4.1.5 VEHICLE ODOMETER READINGS

Vehicle odometer readings are collected and entered into the AirCare database at the time of each inspection. By tracking odometer readings over time, a vehicle's annual distance travelled can be determined. Due to the fact that AirCare inspections do not necessarily occur on an annual basis, the increment of odometer readings on successive tests is adjusted to a 365-day period. Figure 17 below shows the relationship between the number of kilometres driven per year and model year. The data show a fairly consistent decline in annual distance from 18,000 – 20,000 km for recent model year vehicles down to about 14,000 km for 1985 model year vehicles.

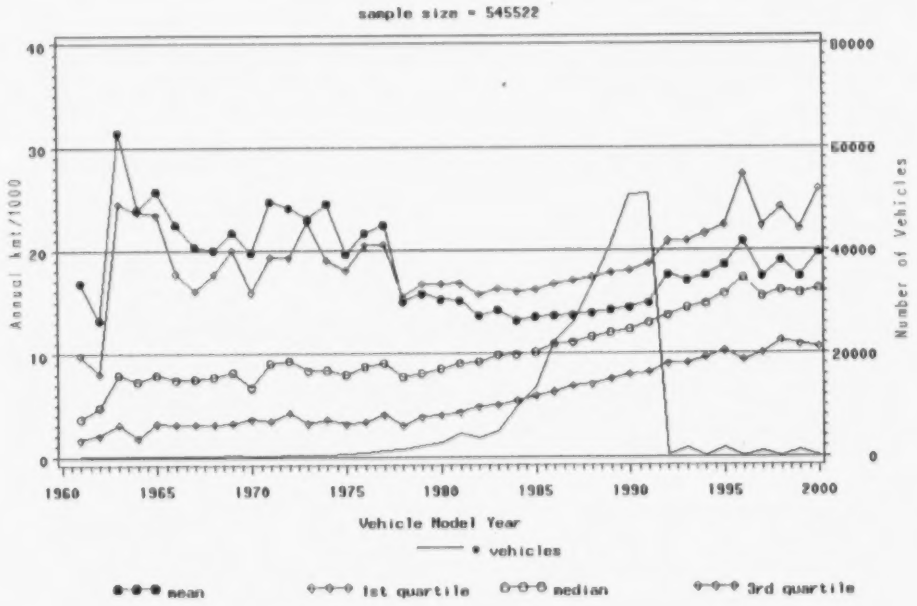

Figure 17. Mileages vs. Model Year of Vehicles

As in previous studies, a sudden change in the data is evident in the late 1970s. It is believed that this change is caused by the conversion from miles to kilometres that occurred in Canada during this time period. Even though the data from 1977 and older are corrected by converting to kilometres, it is possible that the lane inspectors are already converting the reading at the time of data entry, as it seems highly unlikely that vehicles more than 25 years old are driven further than new vehicles. The data for the 1992 and newer vehicles suffers from the fact that

the IM240 test is biennial, rather than annual, meaning that only a limited number of vehicles had two successive tests in the reporting period. The data may not be representative of the overall fleet because the only vehicles that would have been required to be tested in both 2001 and 2002 would be those that received a conditional pass in 2001.

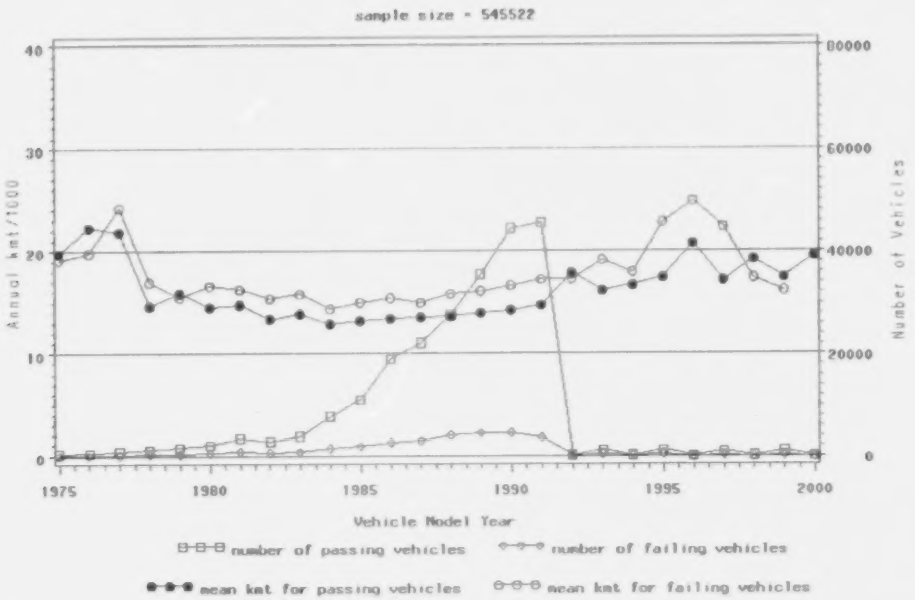

Figure 18. Average Annual Kmt by Model Year

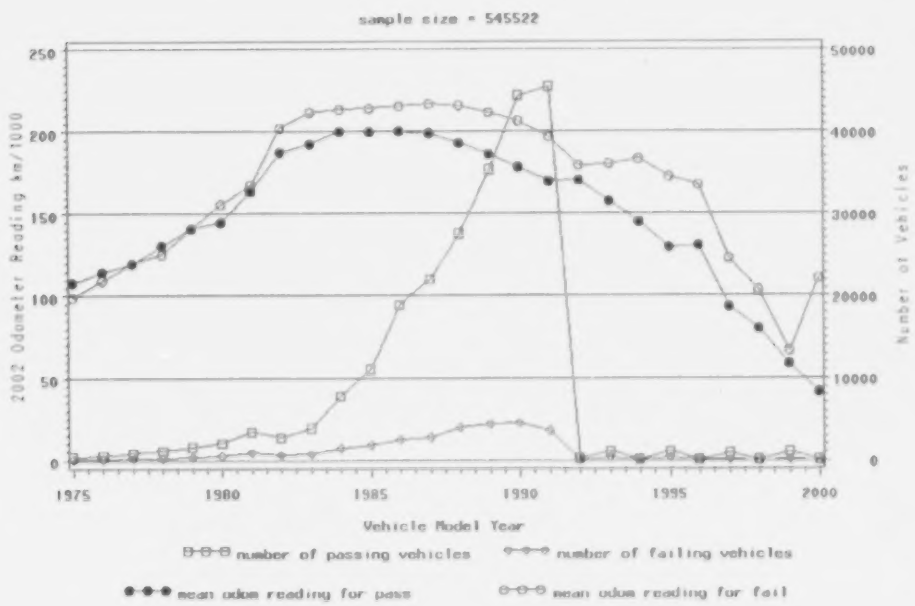

Figure 19. Average Odometer Reading by Model Year

Figure 18 looks at the annual miles travelled for failing vs. passing vehicles. Overall, it appears that failing vehicles travel greater distances per year than passing vehicles. In Figure 19, the mean odometer reading by model year is shown for both passing and failing vehicles. A steady increase is evident in each model year until the odometer reading reaches 200,000 km. Vehicles older than 1985 model year tend to have lower odometer readings. It is probable that these vehicles have survived in the fleet as a result of being driven less frequently than most daily drivers. According to the data, odometer reading tends to decrease with age after the 1985 model year. As would be expected given the indication of higher annual distance driven for failing vehicles, the average odometer reading of failing vehicles is higher than that of passing vehicles of the same model year.

4.2 Inspection Statistics

As expected, the number of inspections performed at AirCare inspection centres during 2001 and 2002 was lower than in 2000. Table 3 shows the number of inspections and the number of vehicles inspected in each of the two years compared to the year 2000.

Table 3. Number of Inspections in 2000, 2001 & 2002

Calendar Year	Number of Inspections
2000	1,074,009
2001	852,621
2002	954,598

According to program design as of January 1, 2001, vehicles from model year 1992 or newer are to be tested on a biennial basis. Therefore, as more and more of the fleet is made up of vehicles from these model years, the proportion of vehicles being tested on a biennial, rather than an annual basis will increase. Theoretically, as the number of vehicles in the 1991-and-older group decreases, the total inspection volume will continue to decline. This will be offset to some degree by an increase in re-inspections as the failure rate increases for aging vehicles.

There are a number of possible outcomes of an AirCare inspection:

- P = Pass
- A = Aborted
- V = Void
- F = Fail
- C = Conditional Pass due to Repair Cost Limit
- Q = Conditional Pass due to incomplete diagnosis by repair technician

Of the above, only P, A, V, or F can occur on an initial inspection. By definition, a conditional pass can only occur after a vehicle has failed one or more initial tests. Starting in September of

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2000, the test database was modified to allow for the provision of a TEST_NUMBER field. This field counts the number of tests received by a vehicle, making it easier to track the inspection history of any vehicle. The counter resets to 0 after every pass or conditional pass result.

4.2.1 FAILING INSPECTIONS

Earlier, in the explanation of the difference between the ASM test and the IM240, it was pointed out that the ASM test lacks the resolution needed to identify abnormal emitters among new-technology vehicles. During the final years of AirCare I, the overall annual failure rate had been declining. This was primarily due to a very low failure rate among 1992 and newer vehicles, which stood at about 2.5% as of the end of calendar year 2000. Although failure rates for the oldest vehicles tested often exceeded 30%, the increased population of newer vehicles with a relatively low failure rate meant that the overall program fail rate was held to about 10%.

Due to the greater stringency of the IM240 test procedure, it was expected that the failure rate would increase in 2001.

Figure 20 shows the overall failure rates in 2001 and 2002. In 2001, the overall failure rate started off at about 15%-17% and dropped to just 16% at the end of the year. The 2001 trend shows a step change from the first quarter relative to the remainder of the year. This can attributed to the use of more lenient "phase-in" pass/fail limits for the IM240 test during this period. The cut points are fully explained in Section 3.1.

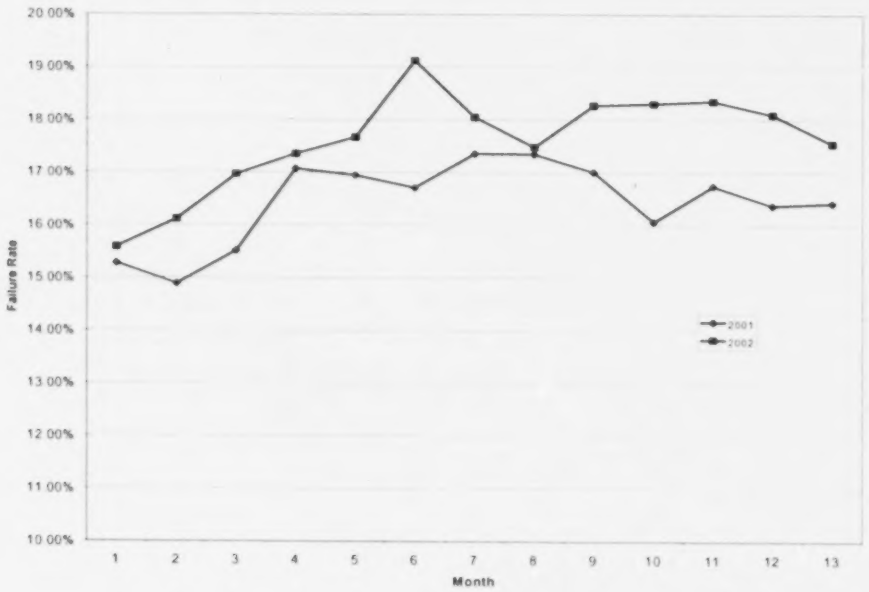

Figure 20. Overall Failure Rates in 2001 and 2002

In 2002, a similar trend can also be observed with one exception. Whereas the failure rate started off at about 15%, it reached almost 20% by June stabilizing at about 18% for the rest of the year. Later in the report, the overall inspection results will be analysed according to the different test types and it will be seen how each test type contributed to the change of the overall failure rates in 2001 and 2002.

4.2.2 FAILING VEHICLES

There are two main methods of expressing the failure rate for the AirCare program. In one sense, the failure rate can be expressed as it was in the previous figures as a percentage of inspections where the result was "FAIL" divided by the total number of inspections performed. This is called the "overall failure rate".

Another method of expressing the failure rate is to take only the first recorded test result for every individual vehicle tested. This method yields the "initial failure rate". This calculation produces a different numerical result than the overall failure rate because it is not uncommon for vehicles to experience multiple failing inspections. Figure 21 shows the failure rate calculated on the basis of the initial test result by month in 2001 and 2002. The initial failure rate is typically 1% to 2% lower than the overall failure rate.

The data shows the initial failure rate was at the range of 14% to 18% throughout the two-year period. In general, the initial failure rate in 2002 was higher than 2001 by 1% to 2%.

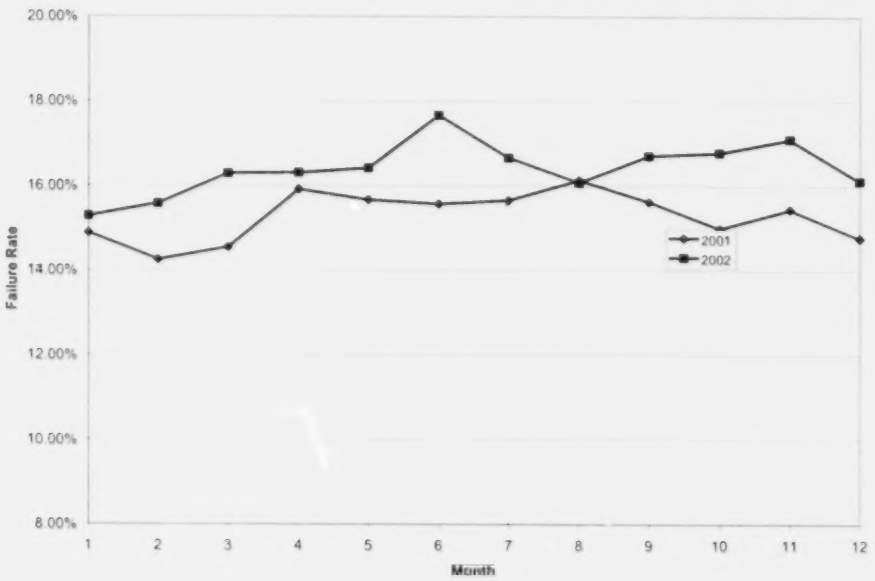

Figure 21. Unique Vehicle Initial Failure Rates by Month in 2001 & 2002

Figure 22 and Figure 23 show the number of failed vehicles and the initial failure rate by model year in 2001 and 2002. The initial failure rates are very similar in both years except for two peaks in 2002 indicating that a significant proportion of model year 1992 and 1994 vehicles failed. In fact, there were more than 14,000 1992-model-year and 10,000 1994-model-year vehicles failed in 2002. More details will be presented in section 4.3.1 with regard to this observation.

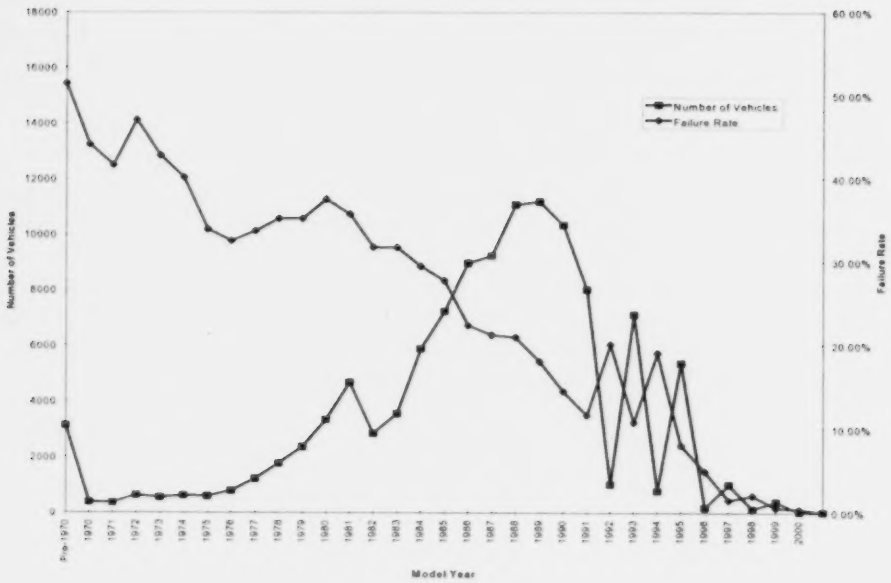

Figure 22. Number of Fail Vehicles and Initial Failure Rate by Model Year in 2001

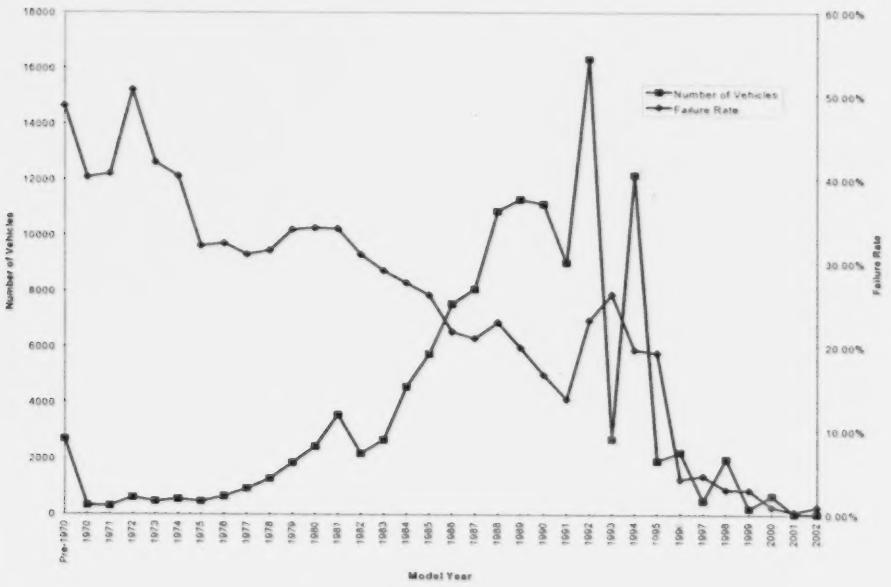

Figure 23. Number of Fail Vehicles and Initial Failure Rate by Model Year in 2002

4.2.3 ABORTED INSPECTIONS

Occasionally, it is necessary to abort a test in progress for any of the following reasons:

- Tire problems
- Excessive Fluid Leaks
- Excessive exhaust leaks
- Vehicle unsafe to operate on dynamometer
- Vehicle unable to follow test trace
- Engine malfunction (i.e. stalling)
- Inaccessible exhaust opening
- Incorrect/missing paperwork
- Sample dilution
- Excessive RPM
- Insufficient funds

In 2001, there were 15,024 tests aborted. In 2002 the figure was 15,723. The most common reason for aborting tests was Sample Dilution. Figure 24 and Figure 25 shows the distribution of the reasons for 2001 and 2002.

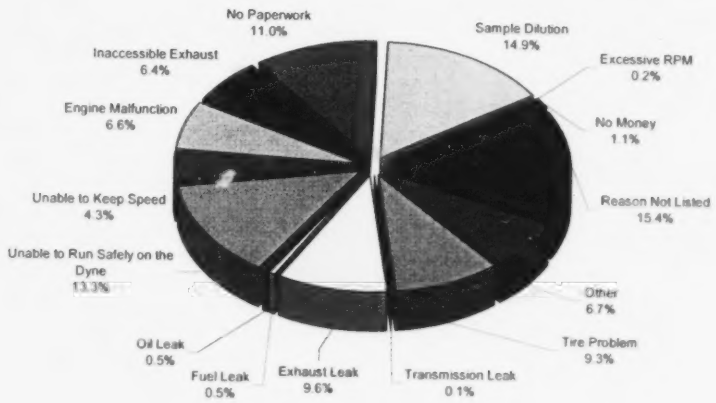

Figure 24. Distribution of Abort Codes in 2001

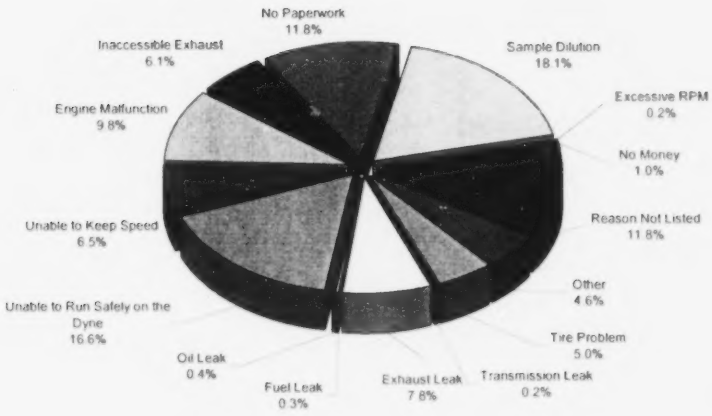

Figure 25. Distribution of Abort Codes in 2002

4.2.4 VOIDED INSPECTIONS

Voiding of an inspection usually occurs after a test has been completed and then an error is discovered. Voiding the test generates a financial credit that is then applied to the subsequent, correct test. A low rate of voided tests is an indicator that proper test procedures are being followed consistently and that customers are receiving good service. There were 791 voided tests in 2001 compared to 881 tests in 2002. It is about 0.09% of all tests performed in each year.

4.3 INSPECTIONS BY TEST TYPE

Figure 26 and Figure 27 show the distribution of inspections by test type, by month in 2001 and 2002. Since there is a large difference in the total volume of IM240, ASM and other test types, the figures were plotted with two scales. The left-hand vertical scale is for the higher volume inspections like the IM240 and ASM/Idle. The right-hand vertical scale is for the lower volume inspections of Idle Only, Diesel and Idle-Diesel tests.

The figures show that there was a fairly consistent level of IM240 tests performed each month. Due to the exemption of vehicles from model years 1992, 1994, 1996, 1998, and 2000 in calendar year 2001, the volume of IM240 tests was expected to be much less than the volume of ASM tests and this proved to be the case. In 2001, there were about 500 Idle-Only and Idle-Diesel inspections performed each month, which is insignificant compared to the other types of inspection. The drop in volume at the end of year is a normal characteristic for that time period and has been observed consistently since 1992.

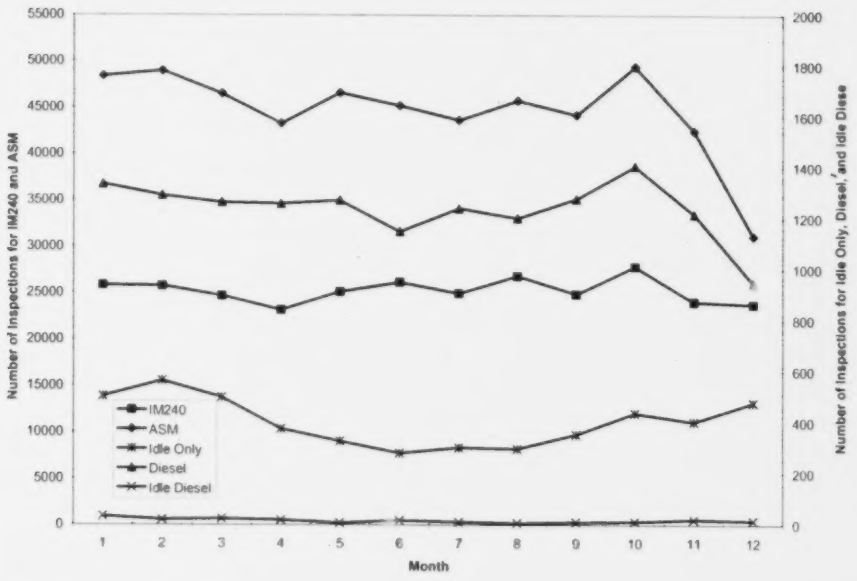

Figure 26. Number of Inspections for Each Test Type in 2001 by Month

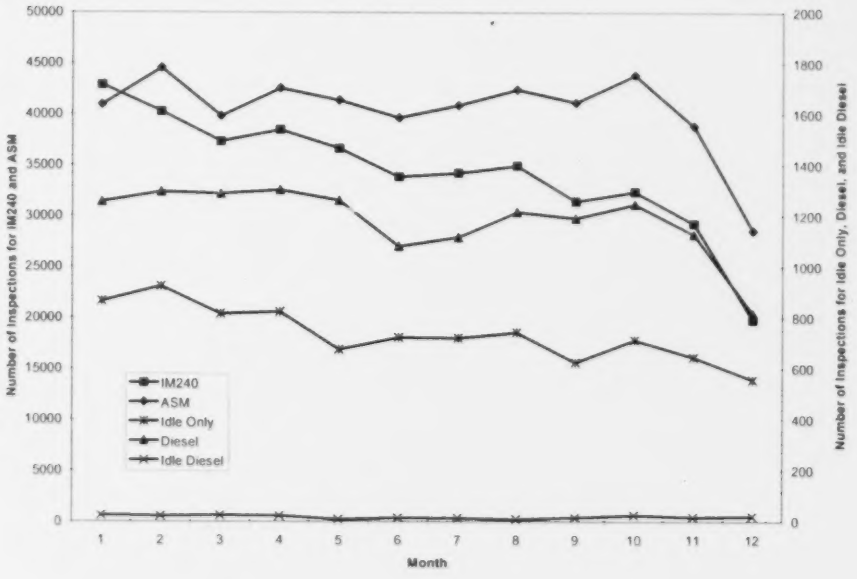

Figure 27. Number of Inspections for Each Test Type in 2002 by Month

In 2002, a marked increase in the number of IM240 tests is indicated.

The ratio of IM240 to ASM tests was 0.635 in 2001 but increased to 0.917 in 2002. This increase was somewhat expected due to the requirement for 5 model years to be tested in 2002

vs. only 4 in 2001. However, this difference does not account completely for the observed increase.

The off-cycle vehicles (1993,1995,1997 and 1999) helped contribute to the increased volume of IM240 inspections in 2002, as explained in section 4.1.2 and in 4.3.1. In 2001, off-cycle inspections represented 7.1% of the IM240 test total. In 2002, this fraction increased to almost 11%.

4.3.1 IM240 INSPECTIONS

Figure 28 shows the overall emissions-only failure rate by month in 2001 for IM 240 tests. The low failure rate of about 3% in the first three months of 2001 was due to more lenient phase-in standards. In April 2001, final standards were put in place and the failure rate immediately jumped to 6%. After the introduction of final cut points, the failure rate increased steadily, reaching almost 12% in the first quarter of 2002, as show in Figure 29. The failure rate hovered between 11% and 13% throughout the rest of 2002. Overall, the failure rate for IM240 test in 2001 was 5.86%. The 2002 failure rate was more than double this, at 12.02%.

One of the reasons is believed to be due to the inclusion of model year 1994 trucks and 1992 model year vehicles in calendar year 2002, that were both exempt in 2001. Figure 30 and Figure 31 show the failure rate by model year and by vehicle type in 2001 and 2002. Since the off-cycle vehicles that were inspected always have higher failure rates, it should not be a surprise to see that the 1992, 1994 and 1996 model year vehicles that were inspected in 2001 have an unusually high failure rate compared to 1993, 1995, 1997 and 1999 vehicles that were in their "on-cycle". In 2002, the 1993,1995, 1997 and 1999 vehicles being tested "off-cycle" were found to have higher failure rates than the "on-cycle" vehicles of the same years tested in 2001.

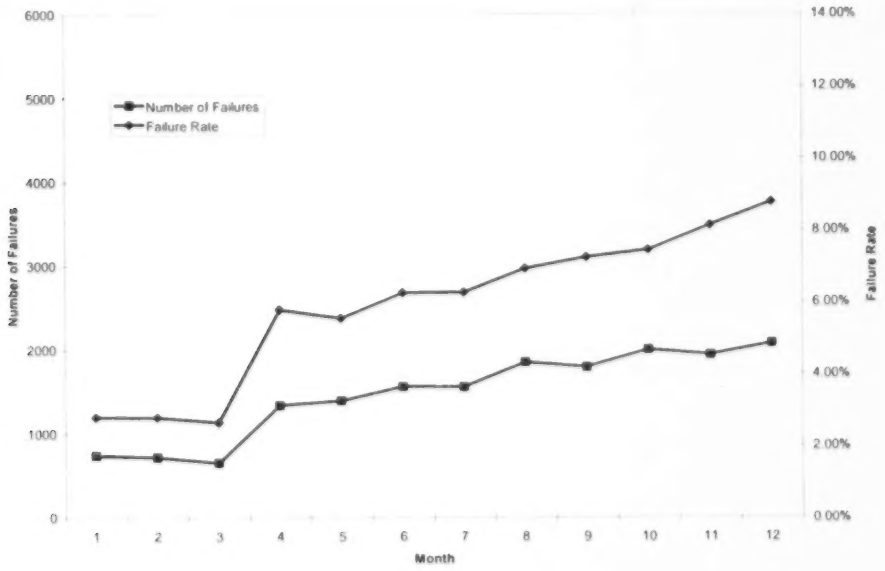

Figure 28. IM240 Number of Failures and Overall Failure Rate by Month in 2001

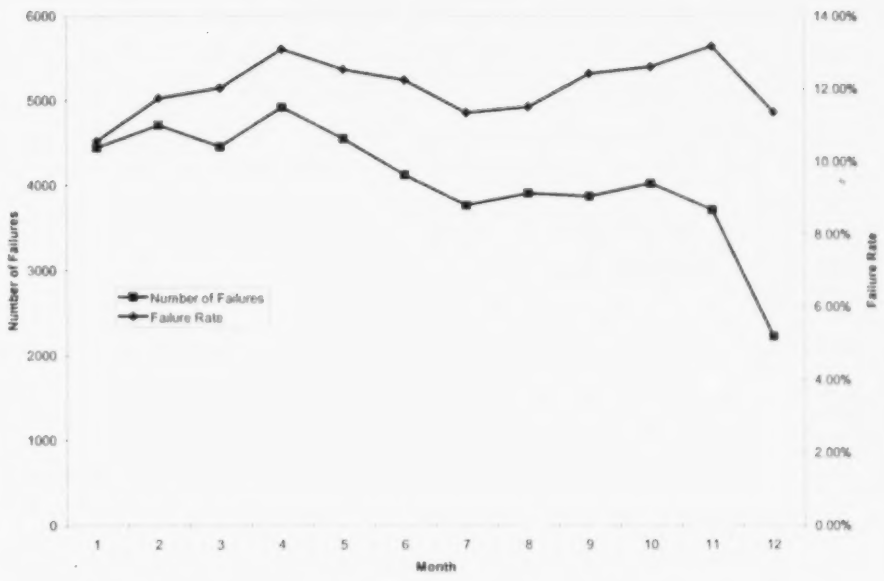

Figure 29. IM240 Number of Failures and Overall Failure Rate by Month in 2002

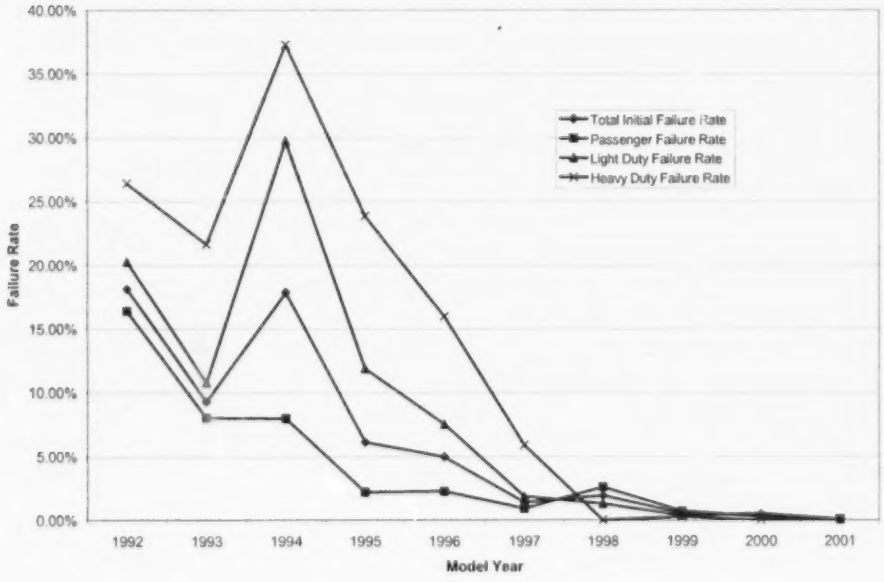

Figure 30. IM240 Initial Failure Rate by Model Year and Vehicle Type in 2001

Figure 30 shows that the initial failure rates of the "on-cycle" vehicles in 2001 ranged from 10% (1993 model) to almost 0% (1999 model). The failure rates for both light- and heavy-duty trucks were always higher than the overall rate. For heavy-duty trucks (greater than 3,856 kg. GVWR), the oldest "on-cycle" model year (1993) had a failure rate of over 20%.

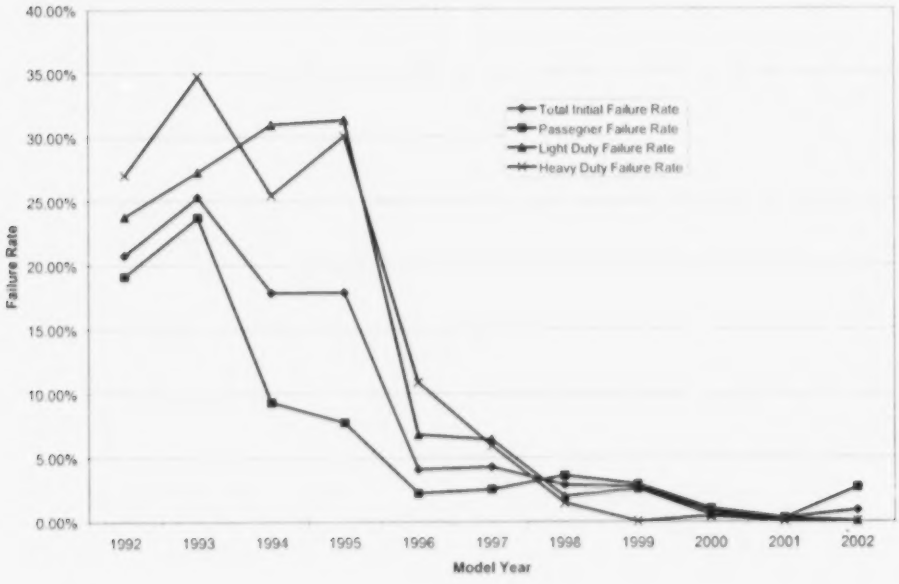

Figure 31. IM240 Initial Failure Rate by Model Year and Vehicle Type in 2002

In 2002, the oldest vehicles subject to IM 240 testing came into their "on-cycle year". This had a large effect on the overall failure rate, as the 1992 model year vehicles tended to fail at a rate better than 20%. For all model years combined, the failure rate for passenger vehicles was about 10%, but light-and heavy-duty trucks each had more than a 25% failure rate!

The differences found between the 2001 and 2002 calendar years is largely due to the fact that totally different proportions of model year and control technology groupings were tested in each year. The graphs show a distinct difference in the failure rate coincident with the 1996 model year. This is the point at which U.S. EPA Tier 1 emission standards were fully phased-in in the United States (40% of 1994 models and 80% of 1995 models were Tier 1 compliant). Although Canada did not make Tier 1 compliance necessary until 1998, almost all the vehicles sold in Canada from 1996 on were Tier 1 calibrations and the phase-in proportions were likely equivalent. The preceding certification standards, called Tier 0, appear to associate with less robust control technology than Tier 1. This, combined with the fact that 1992 model year vehicles are now 10 years old, means that any calendar year grouping with a high proportion of Tier 0 vehicles will have a higher failure rate than one reflecting a lot of Tier 1 vehicles.

In both 2001 and 2002, the most common failure mode was NO_x alone. NO_x-only failures accounted for about 37% of all initial failures in each year. The next most common failure mode was HC-only and combined HC-and-CO failures.

4.3.2 ASM /IDLE INSPECTIONS

As shown in Figure 32 and Figure 33, the overall failure rates for 1991-and-older vehicles tested to the ASM 2525/Idle test procedure were fairly stable throughout the review period. In 2001, the failure rate ranged from 17% to 21%. This increased to between 18% and 23% in 2002. However, the absolute number of failing vehicles was less in 2002 than 2001because the fleet size of 1991-and-older vehicles was smaller.

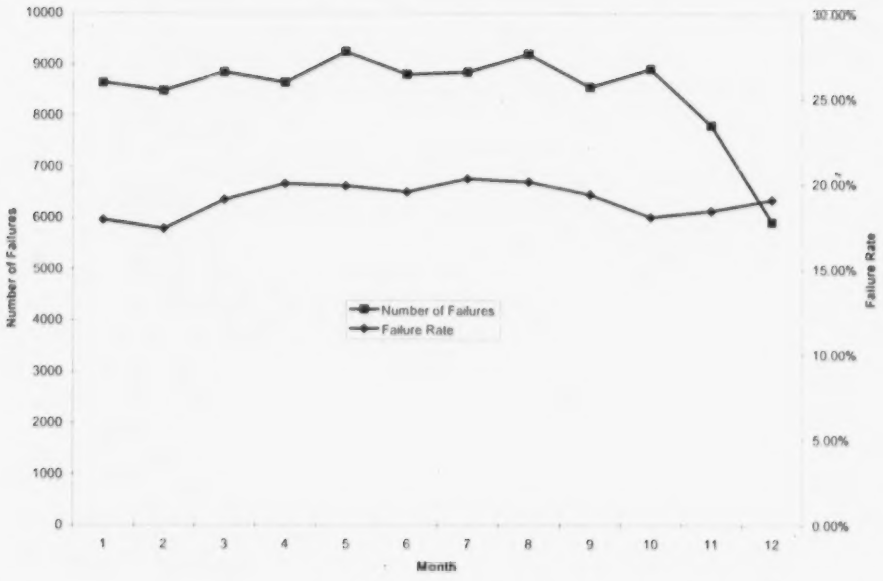

Figure 32. ASM+Idle Number of Failures and Overall Failure Rate by Month in 2001

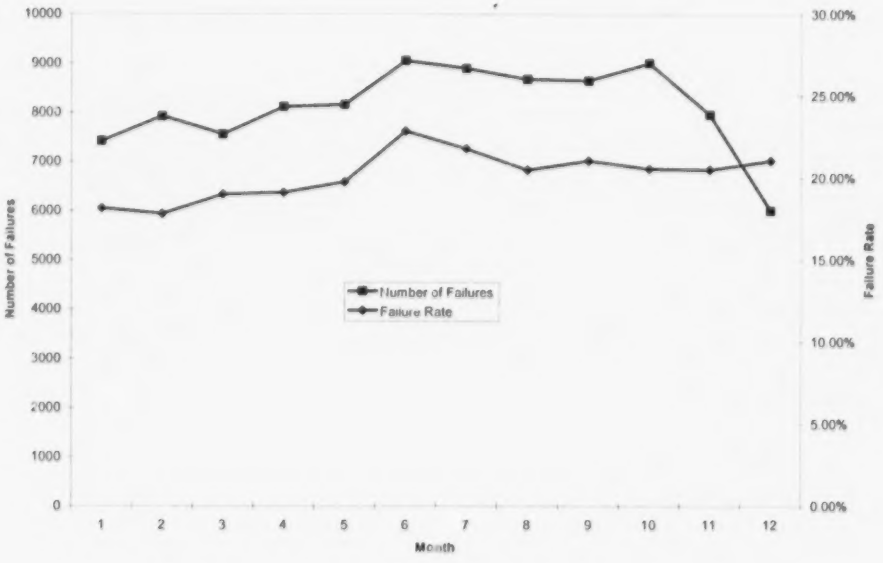

Figure 33. ASM+Idle Number of Failures and Overall Failure Rate by Month in 2002

Figure 34 and Figure 35 show the initial failure rates for ASM/Idle tests by model year and vehicle type in 2001 and 2002, respectively.

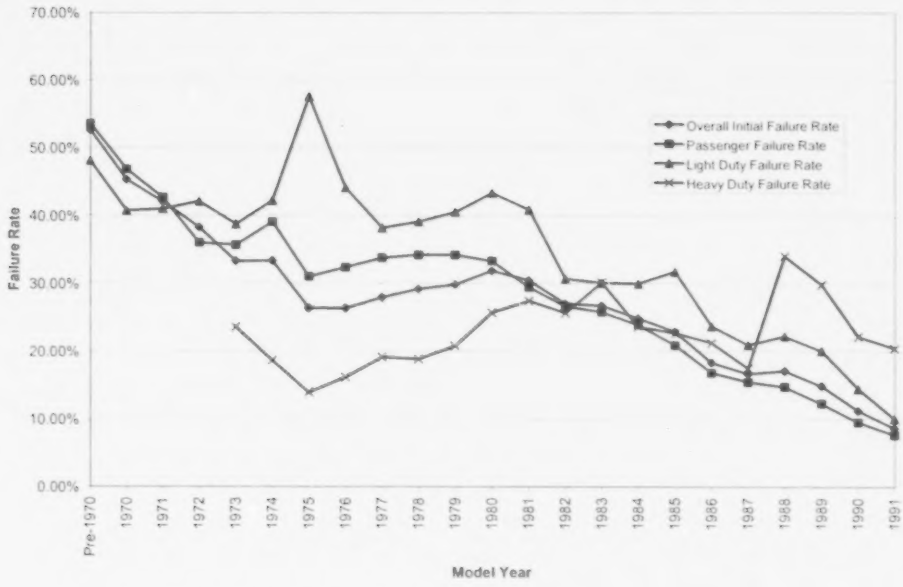

Figure 34. ASM+Idle Initial Failure Rate by Model Year and Vehicle Type in 2001

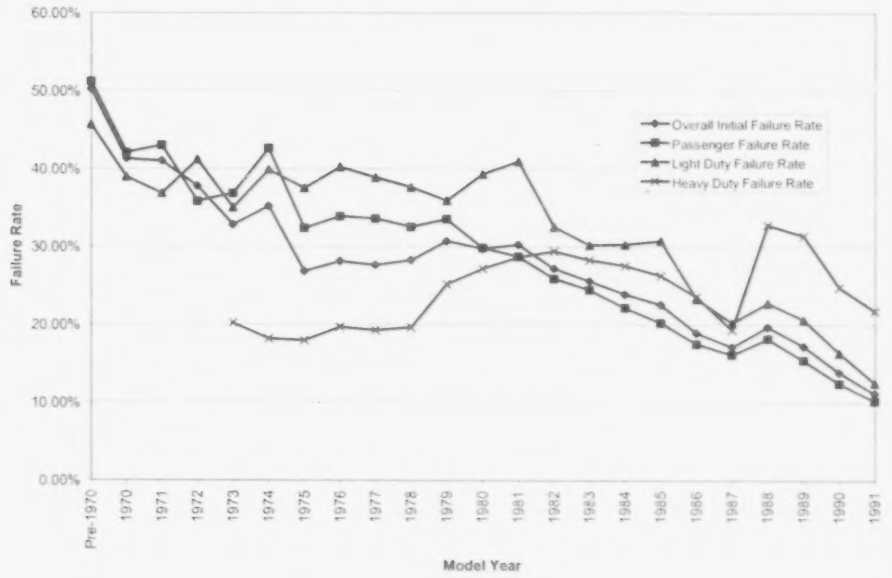

Figure 35. ASM+Idle Initial Failure Rate by Model Year and Vehicle Type in 2002

The trends for both 2001 and 2002 are very similar. Overall, it may be said that the older the vehicle, the higher the failure rate. However, in the case of heavy-duty trucks (greater than 2722 kg GVWR for pre-1988, greater than 3,856 kg. for 1988-1991), the pre-1980 trucks have a lower failure rate than 1981-and- newer trucks. Beyond 1972, all trucks are considered to be light-duty.

There is a step change evident in the failure rate for heavy-duty trucks of model year 1988 or newer. This model year coincides with a change in emission control technology and a corresponding increase in the stringency of the pass/fail standards. The definition of "heavy-duty" truck for 1988 and later model years means that the relative sample size is much smaller. This could also have an effect on the average results for this vehicle type.

As with the IM240, the most common failure mode for the ASM/Idle test was NO_x only. There are five possible combinations of pollutant/operating mode for this test. These are ASM HC, ASM CO, ASM NO_x, Idle HC and Idle CO. ASM-NO_x-only failures accounted for 25% of all initial failures for this age group in 2001 and 22% in 2002. The two next most-common failure modes were Idle-HC-only and ASM-CO-only. This result was the same for both 2001 and 2002. ASM-CO-only accounted for about 10% of failures in both years. The proportion of Idle-HC-only failures increased from 11% in 2001 to 17% in 2002. More details on failure modes will be provided in section 7.1.3.

4.3.3 IDLE-ONLY INSPECTIONS

In order to correctly identify the highest possible number of excess-emitting vehicles, a loaded dynamometer test is preferred to unloaded tests. However, in some cases, it is not possible to test a vehicle in any other way. Possible reasons for not performing a dynamometer test include: lowered chassis, trucks with exhaust terminating ahead of the rear axle, vehicles fitted with studded snow tires (legal only from October through April), and vehicles fitted with handicap controls. In such cases, an idle test is prescribed. The vehicle is subjected to preconditioning at 2500 rpm for 15 seconds. A 30-second sample of idling emissions is then taken. If the recorded readings for HC and CO are below the applicable pass/fail standard, the vehicle passes. If the results of either or both emissions are greater than the allowable maximum, a second 15-second preconditioning cycle is performed, followed by a second idle sample. If the results of this second test indicate passing results, the first results are ignored and the vehicle is declared to have passed.

The addition of four-wheel drive dynamometers has greatly reduced the number of idle-only tests performed at AirCare. In the final year of AirCare I, there were more than 73,000 idle tests performed. By comparison, there were 4,800 idle-only inspections in 2001 and 8,800 such inspections in 2002. The reason for this significant jump in 2002 is because more and more newer model vehicles have low-profile tires, which can be damaged by the restraining devices that are required in IM240 inspection. In 2001, there were 1,774 model year 1992-and-newer vehicles inspected according to the idle test. In 2002, this number jumped to 4,943.

Figure 36 and Figure 37 show the overall failure rates and numbers of inspections by month for idle tests in both 2001 and 2002. Even though the idle-only inspection is considered to be the least demanding emission test, the failure rates in 2001 and 2002 were between 14% (lowest in 2001) to over 20% (highest in 2002).

In 2001, more vehicles were tested using the Idle test procedure during winter similar to the trend found in AirCare I. This has been attributed in the past to the fact that studded snow tires are legal in B.C. during the winter months and studs cannot be used on a dynamometer. Figure 37 shows a deviation from this trend in 2002. In this year, the number of idle tests performed in November and December was lower than during the summer. This change is likely attributable to procedural changes that have made it possible to test more low-profile tire vehicles on the dynamometer, rather than to a decline in studded snow tire use.

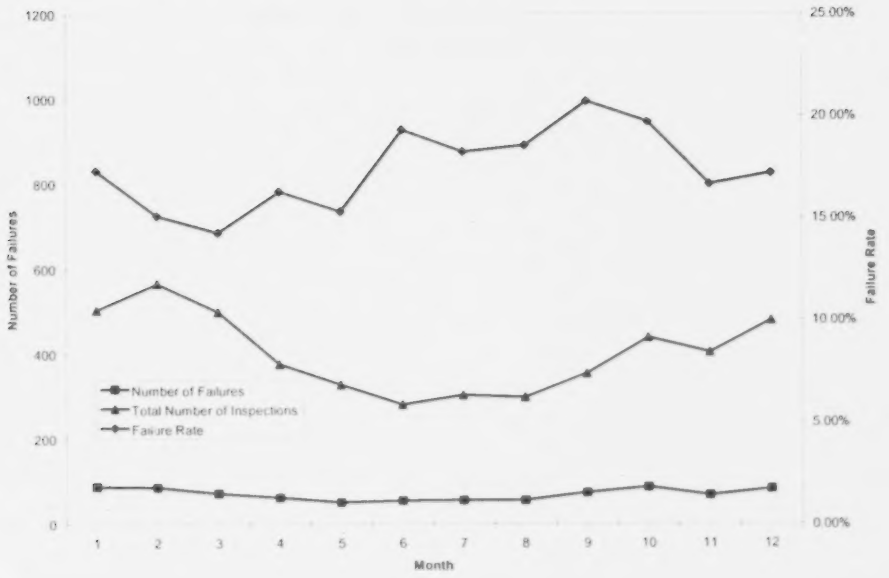

Figure 36. Idle-Only Overall Failure Rate and Number of Inspections by Month in 2001

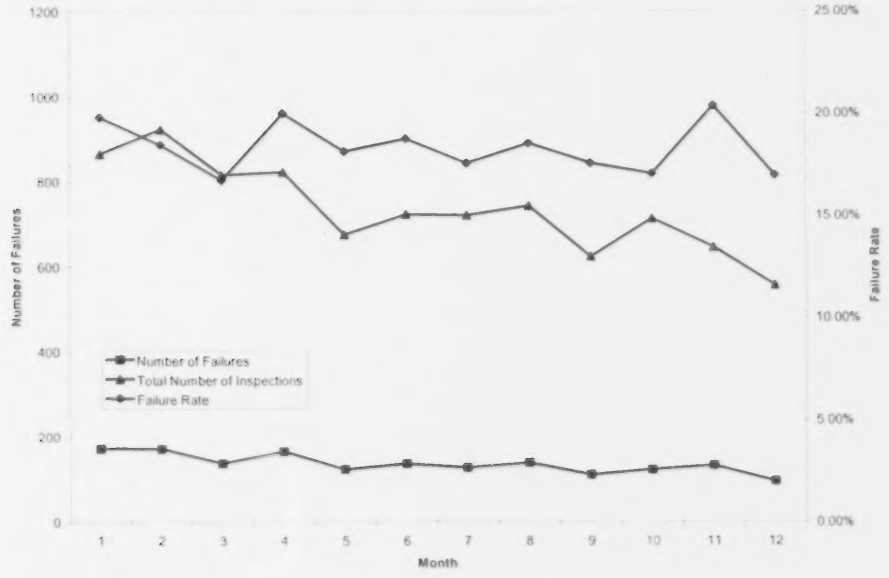

Figure 37. Idle-Only Overall Failure Rate and Number of Inspections by Month in 2002

The small sample size for Idle–Only tests results in a great deal of scatter in failure rates by vehicle type and model year as shown in Figure 38. As mentioned earlier, a higher proportion of recent-model-year vehicles are factory-fitted with low profile tires. Some others are retrofitted with ultra low profile tires to enhance appearance and/or performance. Along with other aftermarket vehicle body modifications, the incidence of "Lowered Chassis" as the reason for

idle-only inspection increased from 45% in 2001 to 55% in 2002. Another significant increase was observed in the "Wheel Base" reason. This is attributable to the introduction of all-wheel-drive systems on full-size pick up trucks that often have wheelbases longer than the 4-wheel-drive dynamometer can accommodate (Max 125 inches).

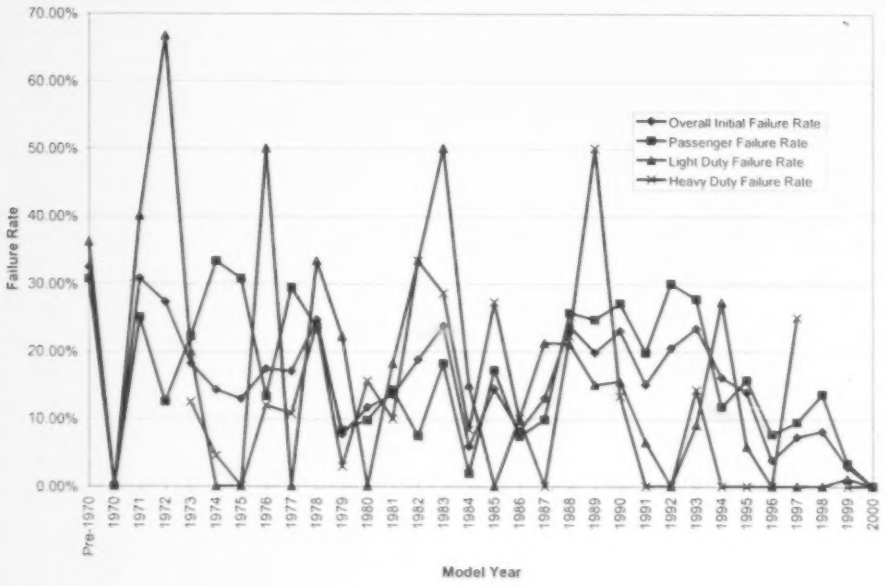

Figure 38. Idle-Only Initial Failure Rate by Model Year and Vehicle Type in 2001

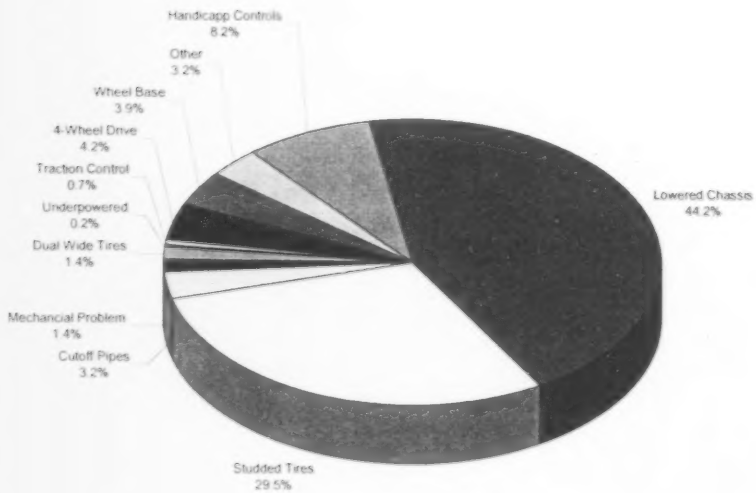

Figure 39. Reasons for Idle-Only Inspection in 2001

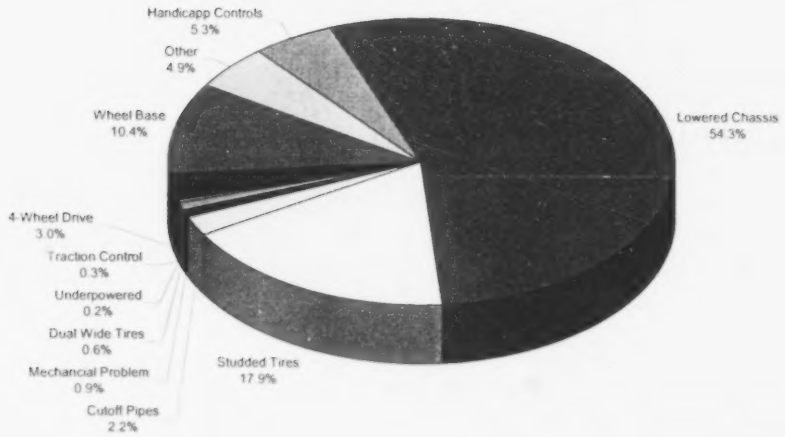

Figure 40. Reasons for Idle-Only Inspection in 2002

On a positive note, most traction-control-equipped vehicles were tested on the dynamometer. As a result, "Traction Control", which was traditionally one of the most common reasons for idle-only inspection, is now less than 1%.

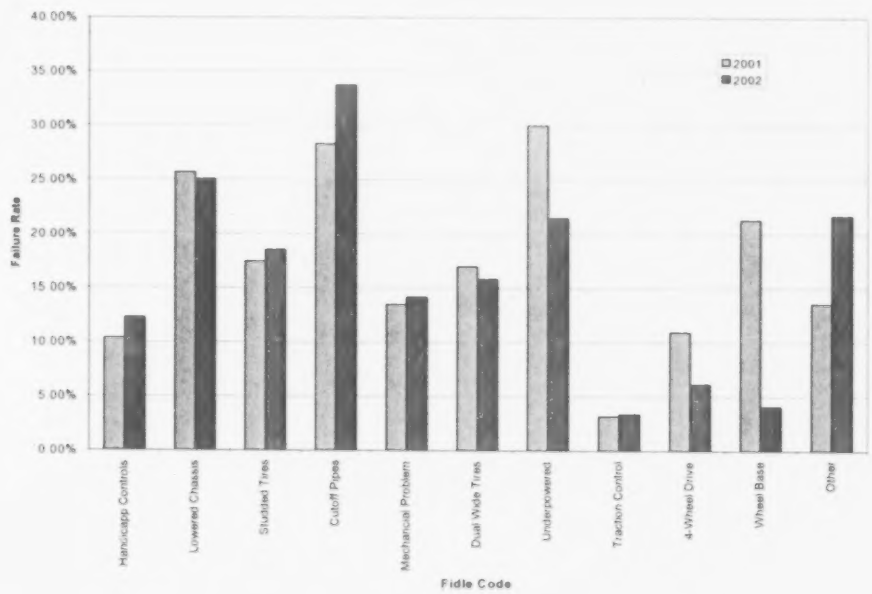

Figure 41. Failure Rates by Reasons of Idle-Only Inspection in 2001 and 2002

Figure 41 shows the failure rates by reasons of idle-only inspections in 2001 and 2002. The failure rates of "Lowered Chassis", "Cutoff Pipes" and "Underpowered" ranged between 25% and 30% in 2001. The failure rates of "Lowered Chassis" and "Underpowered" dropped below 25% in 2002, whereas the failure rate of "Cutoff Pipes" increased to 34%. "Cutoff Pipes" are almost exclusively limited to trucks as they are illegal on passenger cars. A significant drop in failure rate can be observed in "Wheel Base" category. The failure rate dropped from over 20% in 2001 to less than 5% in 2002.

In general, idle-only tests should be viewed as the least-preferred test type for any I/M program. The excess-emitter identification rate for idle tests is much lower than for dynamometer tests and the risk of false failures due to insufficient preconditioning, even with a second-chance feature, is higher than it is for a loaded dynamometer test. Fortunately, this type of test is used in relatively few cases in the AirCare program. While the failure rate seems high for the newer vehicles and somewhat erratic throughout, it is difficult to say exactly why this is so. In many cases, the vehicles that cannot be operated on a dynamometer have been modified with different wheels, tires and bodywork. It is possible that some have been modified under the hood as well. There is no way to confirm this from the data, however. As mentioned earlier, recent procedural modifications have allowed more vehicles to be driven on the dynamometer, reducing the number of idle-only tests. AirCare program administrators will continue to examine the test results from these vehicles and will maintain a position that idle tests are to be used as a last resort only.

4.3.4 Diesel Opacity Inspection

The number of diesel vehicles inspected in 2001 and 2002 was 13,830 and 13,503, respectively. The population of diesel vehicles has remained relatively stable over the past few years. As explained in 3.2, the diesel opacity test is performed in the same manner for all diesel vehicles regardless of age and the results are adjusted for effective optical path length. The test comprises a transient dynamometer driving cycle taken from the second phase of the IM 240 cycle. This phase, 147 seconds in length has been dubbed the D147; "D" for diesel and 147 for the number of seconds in the test cycle. Similar to IM240 and ASM/Idle inspections, some vehicles that are not suitable to be tested on a dynamometer will receive a non-loaded test. For diesel vehicles, this consists of raising the engine rpm with the transmission in neutral or Park and observing the opacity. Without a load on the engine, failing such a test is very unlikely. As with gasoline vehicles, an unloaded test is regarded as a last resort

The overall failure rates for D147 inspections by month in 2001 and 2002 are shown in Figure 42. In general, the failure rates in 2002 were consistently lower than in 2001. The overall failure rate for diesels in 2002 was 6.4% compared to 8.1% in 2001.

The improvement of diesel vehicles is more significant when shown as in Figure 43. The model years with the largest number of failing vehicles were those between 1980 and 1987. For vehicles in this model year range, not only did the failure rate drop from 2001 to 2002, the number of failing vehicles also dropped significantly. There were 185 model year 1986 diesel vehicles failed in 2001, but this number dropped to 105 in 2002. The 100% figure shown for 1972 model year should be ignored as it represents only one vehicle.

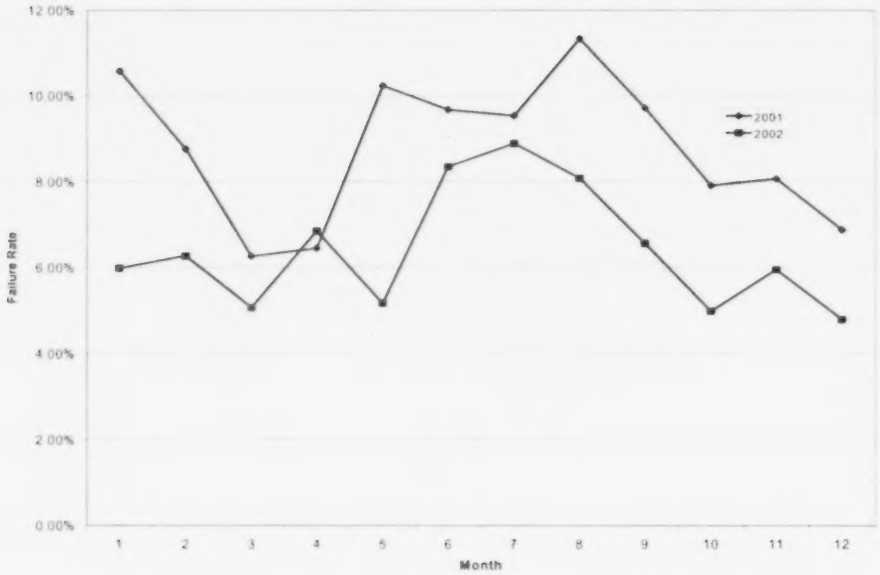

Figure 42. D147 Overall Failure Rates by Month in 2001 and 2002

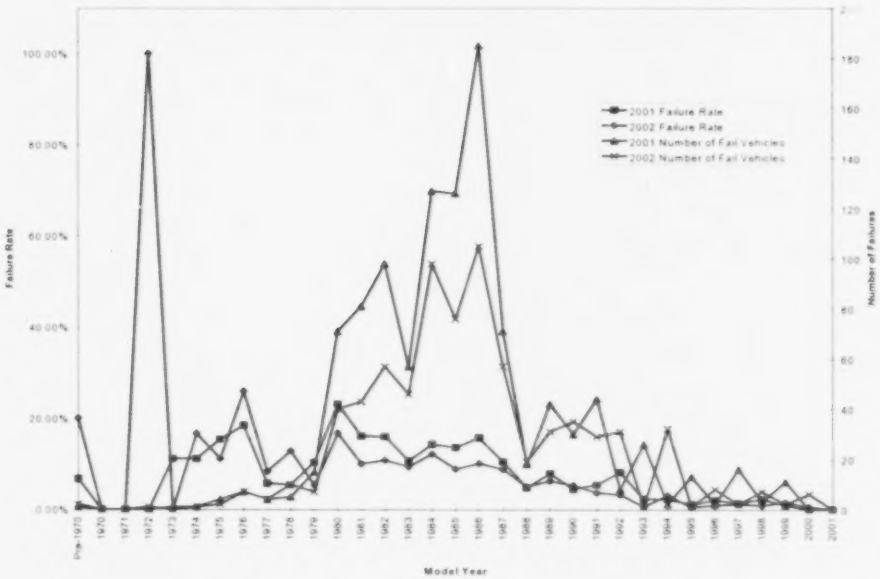

Figure 43. D147 Initial Failure Rates and Number of Fail Vehicles by Model Year in 2001 and 2002

For model year 1992-and-newer vehicles, D147 testing is required on a biennial basis. As with gasoline vehicles fluctuations due to "on-cycle", "off-cycle" effects are evident, however, the failure rate is low in all cases.

There were 184 and 189 diesel vehicles inspected according to the non-loaded test procedure in 2001 and 2002, respectively. The most common reasons for idle-diesel inspection in 2001 and 2002 were "Studded Tires" and "Dual Wide Tires". The "Dual Wide Tires" applies when the track of the drive axle is wider than the dynamometer rollers due to the use of dual rear tires. Since idle-diesel test only takes a snap shot of the opacity as the vehicle is running at idle, it is very rare to have any vehicle fail the test unless it has some kind of major engine problem. In fact, there was only one failure in the entire two-year review period.

4.3.5 GAS CAP PRESSURE TEST

In AirCare I, vehicles could fail the test due to a missing catalytic converter (model years 1988 and later) or a missing gas cap, regardless of the tailpipe emission result. These provisions have carried over into AirCare II but have been supplemented by the addition of a functional test of the gas cap.

Vehicles that fail only the gas cap portion of the test do not have to go through the whole test again. Instead, the new cap is presented to the station manager where it is tested using a hand-held tester and the same adapters as used in the inspection lanes. If the replacement cap passes the re-test, an administrative procedure is invoked to override the failure. Thus gas cap failures may appear in the database as an overall fail, but there will be no re-inspection to balance it.

Figure 44 and Figure 45 show the monthly progression of gas cap failures in terms of numbers and percentage of vehicles tested. A step change in the failure rate is evident in July of 2001. Although no changes were made to the test equipment or procedure at this point, the AirCare contractor issued an operations alert establishing a standardized procedure for carrying out the tests. It appears that this procedural change was responsible for the change in fail rate.

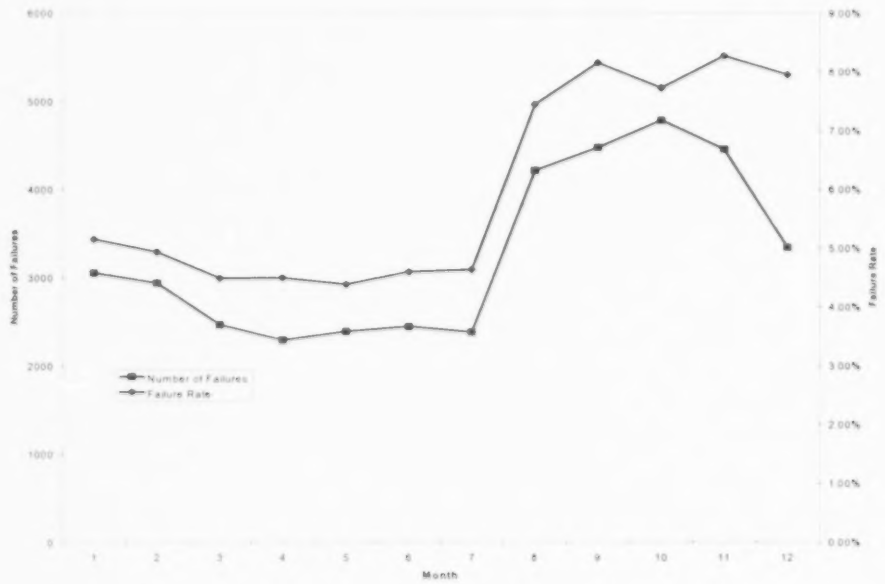

Figure 44. Gas Cap Overall Failure Rates by Month in 2001

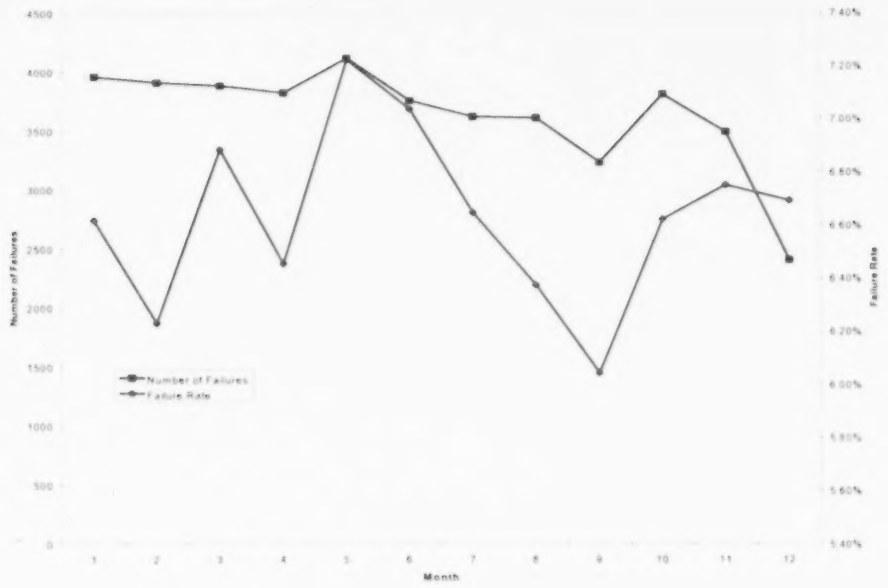

Figure 45. Gas Cap Overall Failure Rates by Month in 2002

It was expected that the failure rate for gas caps would be high in the first year of testing, particularly for the older vehicles. To some degree, this proved to be the case. However, it seemed logical to program administrators that once the defective gas caps had been replaced, the failure rate would drop significantly in the next year. This, however, did not occur as showed in the Figure 45.

In order to investigate why the incidence of gas cap failure did not drop as expected in 2002, an analysis was performed to see if the same vehicles that failed in 2001 had failed again in 2002. If this proved to be the case, the reason could be that the owners of vehicles that failed in 2001 bought a new gas cap only to satisfy the re-inspection requirement, returned the new cap to the place of purchase for a refund and then re-installed the old cap. If this practice was occurring, it would seem logical that these vehicles would fail again the following year.

After analyzing the results, however, it appears that this was not the case. There were only 1,379 cases where the same vehicle failed for gas cap in both years. The gas cap failures noted in 2002 are, in almost all cases, associated with vehicles that passed in 2001. Vehicles that failed in 2001 typically passed in 2002. The numbers are 9,713 and 14,124 respectively. Although most of the passing gas caps have zero pressure drop when tested (i.e. zero leakage), many passing caps were found to be marginally leaking with a pressure loss of about half the standard. There were 26,435 gas caps tested in 2002 that only marginally passed in 2001. Of these, about 10%, or 2,354 caps, failed. Why more than 7000 gas caps changed from passing to failing in one year is not clear. At this mortality rate, a much higher failure rate would have been predicted in 2001 wherein many vehicles had gone up to 20 years without a gas cap pressure test.

When a cap is defective to a point where it cannot hold any pressure, a result of FAIL is issued on the inspection form and the test result noted in the database is "D" for "defective". There were 10,688 cases in 2001 and 7,904 cases in 2002 where a "D" result was recorded.

Comparing these numbers to the total number of failed gas caps, tests where no pressure could be sustained against the cap accounted for 40.4% of all the gas cap test failures in 2001, and 36.2% in 2002. The high incidence of this type of failure is a concern because the inability to generate any initial pressure in the test apparatus may not be solely due to the cap being defective. In cases where the adaptor used to mount the cap does not fit properly, the system may indicate a leak that would not be present when the cap is installed on the vehicle. The inability to differentiate between cases of a defective cap and an incompatible adaptor suggest that it is necessary to review current procedures for dealing with cases where the test apparatus cannot generate sufficient pressure to initiate the test.

4.3.6 VISUAL INSPECTION OF EMISSION COMPONENTS

Aside from emission testing, vehicles are visually inspected for missing catalytic converters or gas caps. Prior to AirCare II, visual checks were more comprehensive but the incidence of tampering detected for underhood emission control components was not significant enough to justify the extra time needed. In addition, the process of opening and closing the hood increased the potential for damage claims.

4.3.6.1 Visual Inspection for Catalytic Converter

The catalytic converter is arguably the most important emission control device on a vehicle. For vehicles built between 1975 and 1987, an advisory is issued if a catalytic converter was originally fitted to the vehicle (a number of Canadian vehicles in this period were not) and it is not present when the inspector checks the exhaust system. The advisory has no bearing on the test result as long as the vehicle is able to pass the tailpipe test. On 1988 and newer vehicles, however, the lack of a catalytic converter will result in an automatic failure.

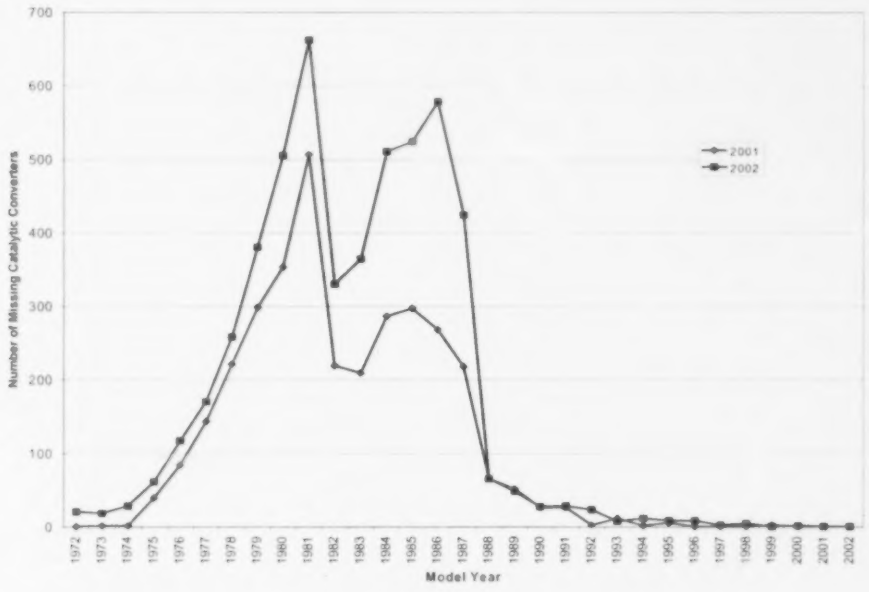

Figure 46. Number of Vehicles with Missing Catalytic Converter in 2001 and 2002

There were 3,332 detected cases of a missing catalytic converter in 2001, or 0.46% of all inspected vehicles. The corresponding values for 2002 were 5,181 and 0.73%. The distributions by model year for both 2001 and 2002 are shown in Figure 46.

According to the figure, the rate of catalytic converter removal is virtually zero until a vehicle reaches 10 years of age. Interestingly, more vehicles were found missing the converters in 2002 compared to 2001. It is not clear whether this is due to an increase in removal rate or to a more diligent visual inspection. The greatest proportion of missing catalytic converters occurs in the 1987-and-older group.

Analysis of the data suggests that few of the converters on these 1987-and-older vehicles are replaced as a result of the inspection. The number of 1987-and-older vehicles entered as missing a catalytic converter was 3,143 in 2001 and 4,949 in 2002. The increase of number of missing catalytic converters suggests there was simply no voluntary replacement.

Repair technicians occasionally report that a vehicle brought in for AirCare repairs is missing its catalytic converter but the inspection result indicates that the converter was present. This suggests that the detection rate of missing converters is not 100%, but the low rate of reports from the repair industry about inaccurate visual inspections suggests that it is not much less.

4.3.6.2 Missing Gas Cap

In 2001, there were 1,410 instances where vehicles appeared for inspection with no gas cap. In 2002, the number was 1,342. The percentage rate works out to an identical value of 0.18% for both years. Figure 47 shows the number of vehicles with missing gas caps by model year in 2001 and 2002.

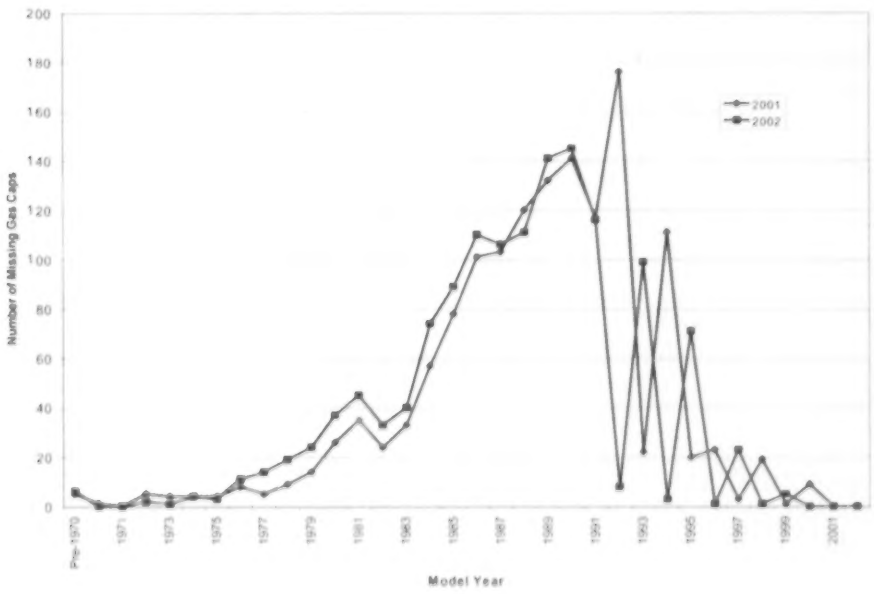

Figure 47. Number of Vehicles with Missing Gas Cap by Model Year in 2001 and 2002

The figure shows that the highest incidence of missing gas caps occurs for vehicles in the 1980-1992 model year range. The biennial effect of IM240 can be observed in model year 1992 and newer vehicles.

4.3.7 On-Board Diagnostic Systems

Inspection and maintenance programs were devised in order to counteract excess emissions resulting from:

- Failure to perform scheduled maintenance
- Undetected or uncorrected failure of emission control devices or emission-related systems
- Deliberate disabling or removal of mission control devices (tampering)

In theory, requiring vehicles to undergo periodic inspection should provide a deterrent against deliberate tampering and identify the need for corrective maintenance for neglected or prematurely-failed emission control components. Although I/M programs have proven to be effective in reducing emissions, they suffer from the fact that inspections occur infrequently and at the discretion of the vehicle owner/driver. Problems may develop soon after a passed I/M inspection and may go uncorrected until the next required I/M test. Owners of vehicles that have a high likelihood of failing may resort to extraordinary means such as temporarily altering engine settings to obtain a passing result and then restoring the vehicle to its previous state. These "false passes" undermine the effectiveness of I/M and contribute to public scepticism about the effectiveness of I/M programs.

Starting in the late 1970s, federal anti-tampering legislation required vehicle manufacturers to develop technical solutions to one of the basic problems that created the need for I/M. Anti-tampering provisions began in earnest with the 1980 model year vehicles. Adjustable parameters such as ignition base timing, idle air-fuel mixture and idle speed were eliminated in the 1980s, helped in large part by the transition from carburetors to electronic fuel injection. Overall, emission control devices have become much more integrated into the engine as opposed to the add-on systems that existed in the 1970s and early 1980s. Engines manufactured in the last decade typically have few if any adjustable parameters. Spark plug life has now reached 10 years, 160,000 km for most new vehicles and many trouble-prone components in the ignition system such as distributor caps and rotors have been replaced by distributorless systems. Coil-over-plug ignition systems have eliminated the need for spark plug wires altogether. The driveability and fuel economy of modern engines is so good that there is little incentive for vehicle owners to tamper with them.

As a result of the above efforts by the vehicle manufacturers, tampering is much less prevalent today than it was years ago. As described earlier in this report, removal of the catalytic converter appears to be the only remaining type of tampering that occurs with any significant frequency.

Neglected maintenance and undetected component failure have been somewhat addressed by reducing the amount of scheduled maintenance that needs to be performed and by increasing the durability of underhood components to reduce the probability of failure. The quality of vehicles and components has increased significantly in the past decade and federal emission legislation has extended the durability requirements for emissions compliance from 80,000 km to 160,000 km for passenger cars and will increase again to 193,000 km when Tier 2 standards

are introduced starting in 2004. For light trucks, the durability requirement has been 193,000 km for many years. As part of Tier 2, manufacturers may opt to certify to a slightly more lenient standard as long as the standards are met for 15 years or 240,000 km. Most vehicles manufactured since the 1996 model year require little scheduled maintenance other than oil changes in the first ten years of use. Since there is little need for routine maintenance, reliance on the owner to have this worked performed is greatly reduced.

Despite the advances in engine and emission control component durability, however, premature failures still occur. As vehicles have become more complex with more electronic controls, the ability of engines to continue to operate acceptably when a defect is present has increased as well. As a result, owners may be unaware of the fact that a problem has developed. Even if they do notice a problem and bring the vehicle in for service, the technician is faced with a greater challenge in identifying the nature of the problem and recommending an appropriate repair. The ability to provide the technician with some assistance in diagnosing problems with computer-controlled engines led to the idea of on-board diagnostic systems.

The concept of on-board diagnostics originated in California in the 1980s. It was intended to provide the capability of identifying faults that would result in excess emissions as well as providing useful diagnostic information for repair technicians. As the capacity of microprocessors increased, it became possible to further enhance the concept. The result was OBD-II. OBD-II systems first appeared on 1994 model year vehicles and were required on all light-duty vehicles by model year 1996. Key features of OBD-II systems are:

- standardized connector location and configuration
- standard diagnostic scanner interrogation protocol allowing one scan tool to be used on all vehicle types
- standard Diagnostic Trouble Codes (DTC's)
- continuous monitoring of components and systems critical to emissions performance

OBD-II systems incorporate a "Malfunction Indicator Lamp" or MIL, to advise the driver that a fault has occurred. The MIL will also flash a warning to the driver in the event that a serious misfire is detected. It is hoped that the flashing MIL will prompt the driver to immediately stop and shut off the engine as driving with a continuous misfire can do serious and permanent damage to the catalytic converter. The OBD-II system also includes a catalyst efficiency monitor along with monitors for fuel system integrity and evaporative emissions canister purge.

The comprehensive nature of OBD-II should allow it to take the place of I/M as the system will effectively identify any of the conditions that I/M programs were designed to detect. Since the system operates continuously, faults can be repaired soon after they occur, resulting in minimal damage to related systems – provided, of course, that the vehicle owner/driver reacts promptly to the illumination of the MIL. It should be remembered that in most cases, the vehicle will continue to operate in a satisfactory manner even with the MIL illuminated, so it is not a certainty that the driver will react to its presence.

4.3.7.1 OBD-II in Lieu of Tailpipe Testing

The U.S. EPA has mandated that all I/M programs use OBD-II interrogation as a substitute for tailpipe testing for 1996-and-newer vehicles commencing in 2003. Flexibility in the requirement,

however, allows states to delay implementation to as late as January of 2005. However, all I/M programs in the U.S. will have made the transition to OBD-II testing by this date.

During the design phase for AirCare II, the requirement to collect OBD-II information was included in the program specifications. Due to the fact that OBD-II systems were not required by law in Canada until the 1998 model year, collection of OBD data at AirCare inspection facilities has been restricted to 1998-and-newer model year vehicles. The information has been collected on an advisory basis, meaning that the results have no bearing on the overall inspection results. The intent was to perform both IM240 and OBD-II testing on the same vehicles, in order to determine if OBD-II systems were capable of identifying excess-emitting vehicles with the same or even greater effectiveness as a tailpipe emission test.

During calendar year 2001, 60,929 OBD-II interrogations were successfully completed. Overall, 466 vehicles were discovered to have the MIL commanded "ON" (0.76%). There were 493 vehicles in the sample that failed the IM240 test, but only 41 of these vehicles also failed the OBD-II check. In other words, although 452 vehicles exhibited tailpipe emissions in excess of the IM240 cut points, 90% of the time, the OBD-II system was not detecting any fault. Conversely, of the 466 vehicles where the OBD-II system had illuminated the MIL, 425 were still able to pass the IM240 test, despite the fact that the OBD-II system had detected a fault within the vehicle.

In calendar year 2002, the number of OBD-II interrogations increased significantly, due to the fact that both 2000 and 1998 model year vehicles required testing. In total, 143,146 OBD-II interrogations were performed, 63,307 from the 1998 model year and 71,296 from the 2000 model year. Overall, 2,039 were determined to have the MIL commanded "ON" (1.42%). Of these, only 328 failed the IM240 test as well. There were 2,865 vehicles that failed the IM240 test even though the OBD-II system indicated a clean bill of health.

The results for both years are shown as Venn diagrams in Figure 48 and Figure 49.

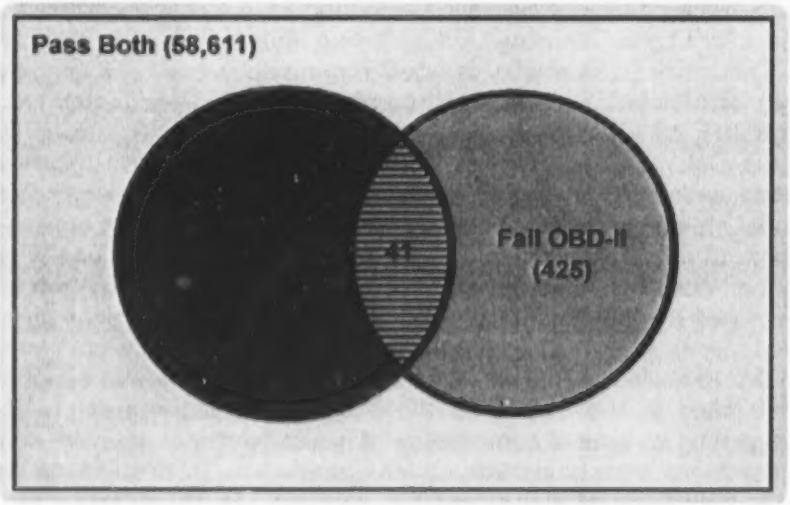

Figure 48. Illustration of OBD-II vs. IM240 Results in 2001

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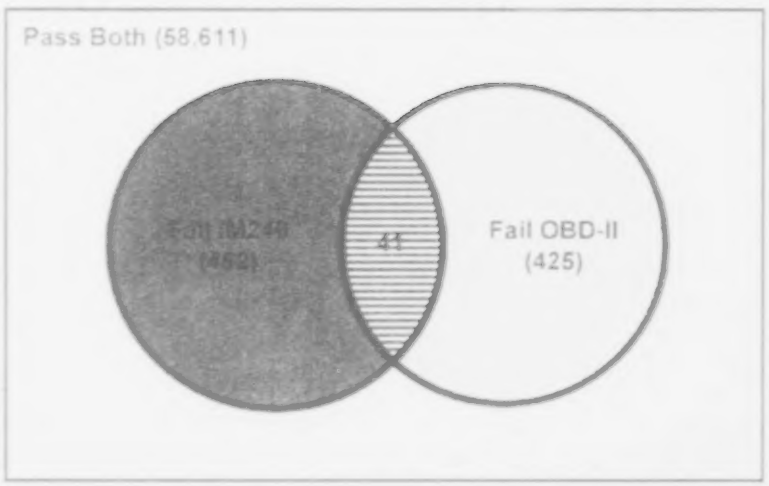

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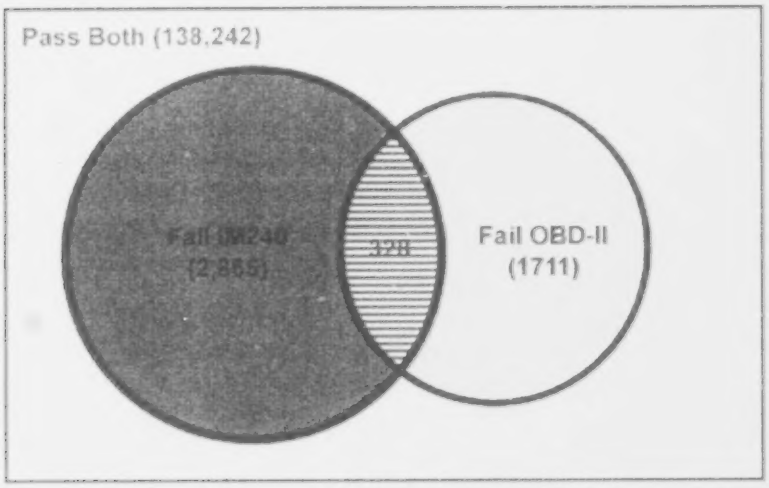
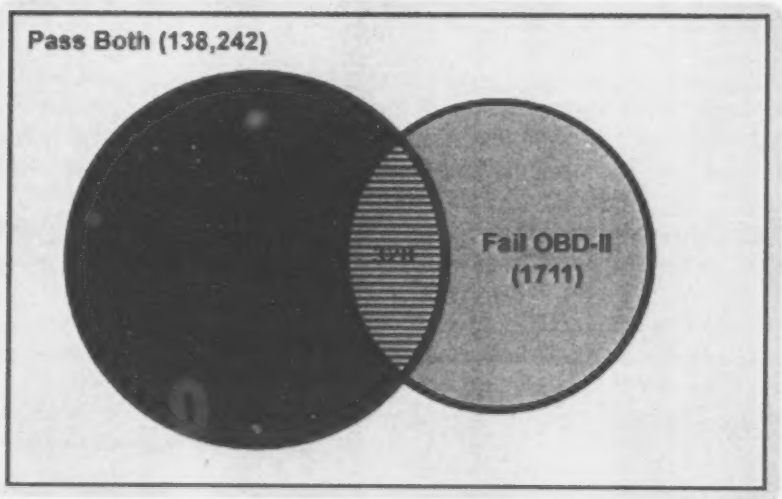


Figure 49. Illustration of OBD-II vs. IM240 Results in 2002

As can be seen from the diagrams, there is little overlap between the two test methods. In 2001, there were equal (and small) numbers of vehicles that failed either the OBD-II test or the IM240 test. Only 41 of these vehicles failed both tests. In 2002, the number of vehicles that failed the IM240 test was quite a bit larger than the number that failed for OBD-II only. The overlap was 328 vehicles.

The lack of overlap between the OBD-II and IM240 results has been observed in other I/M programs where parallel tailpipe and OBD-II testing has been performed. The natural concern arising from this observation is that there must be some degree of error in one or the other method if disparate conclusions are reached regarding the emissions performance of the same vehicle. The U.S. EPA performed some in-depth studies in a report entitled "Evaluation of On Board Diagnostics for Use in Detecting Malfunctioning and High Emitting Vehicles", published in August, 2000. This study involved 201 vehicles from model years 1996 through 2000, of which 194 had the MIL illuminated. Full cold-start certification tests were performed on all of these vehicles. Of the 194, 89 vehicles exceeded the FTP standards. The study also procured 17 vehicles from the Colorado I/M program inspection lanes that were observed to have high tailpipe emissions according to an IM240 test but did not have the MIL illuminated. When subjected to an IM240 test in the laboratory, however, 15 of the 17 were observed to pass. The study did manage to obtain 8 vehicles that had bona fide high emissions when tested to the IM240 cycle in the laboratory. Five out of these 8 vehicles failed the FTP test. When repaired, the vehicles that failed the IM240 test exhibited greater emission reductions on average than the vehicles repaired following an OBD-II failure, however, more vehicles were identified using OBD screening than IM240 testing. What was concerning about this study was that a high proportion of vehicles that failed in the inspection lanes passed a subsequent re-inspection in the laboratory – suggesting an error of commission. It is also worthy of note that some vehicles with verifiably high emissions were found with no MIL illumination. This suggests that OBD-II is not 100% effective in identifying all excess-emitting vehicles. However, in the study, more of the vehicles that had the MIL illuminated were found to be genuine high emitters and the total emission reductions achieved by successfully repairing these vehicles were greater than those achieved from the IM240 group.



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The conflicting results from OBD-II versus IM240 testing make it difficult to conclude whether one method should be adopted over the other. However, one clear advantage of OBD-II testing lies in its simplicity. When a vehicle fails an OBD-II test because the MIL is on and trouble codes are stored, there is a high probability that some form of repair action will be taken. The success of the repair will be easily verified by the MIL remaining out. In the case of an IM 240 failure where there are no stored codes, a technician must perform a number of diagnostic tests and apply considerable judgement to determine an appropriate repair strategy. Unless a clear fault is discovered during diagnosis, the outcome of the process might be that the vehicle be re-tested without repairs or that a generic solution be applied such as a new catalytic converter, oxygen sensor or both. An analysis of repair data for 1998 and newer vehicles indicates that repair data was submitted in 899 cases out of 3,193 vehicles that failed the IM 240 test (28.2%). Therefore, more than 70% of these vehicles simply returned for re-inspection and passed with no details as to what occurred between the failing and passing tests.

The program administration office has encountered bona fide cases where NO_x emissions have been well above certification standards according to a tailpipe test with no indication of a vehicle fault from the OBD-II system. Due to the sensitivity of NO_x conversion in the catalytic converter to air-fuel ratio, the OBD-II system may not detect a slight lean shift that would be enough to have a significant impact on NO_x output. These cases would appear as tailpipe failures but OBD-II passes. According to the California Air Resources Board, NO_x emissions may be able to reach three times the certification standard at the point where current HC-based catalyst efficiency monitors would trigger the MIL.

At present, there does not appear to be much to be gained by switching from one test to the other. Parallel testing should continue for the foreseeable future in order to assess how the two tests fare as the 1998-and-newer fleet becomes older.

5.0 AUDITING AND QUALITY ASSURANCE

AirCare is a mandatory program that may require vehicle owners to spend hundreds of dollars on repairs in the event of a failure. Therefore, it is very important that the test be administered correctly and that all analytical equipment be functioning within its stated tolerance for accuracy.

Numerous performance standards are outlined in the contract between the AirCare contractor and Translink. In order to ensure that the appropriate service levels are being delivered, PVTT performs regular audits at all inspection facilities. Each inspection facility and every lane is audited once per month. Deficiencies noted are identified to the facility manager during the audit and many are corrected prior to completion of the audit. In some cases, it may be necessary to close a lane until the necessary calibrations or maintenance work can be performed.

The PVTT auditor prepares a monthly report summarizing the results of the audit checks performed, the status of corrective actions in response to any deficiencies and recommendations for remedies in the event of contract violations. Regular meetings are held with the AirCare contractor to discuss performance issues such as excessive wait times, incorrect test procedures and customer complaints.

The auditor schedules visits to each inspection centre once per month. The order in which audits are conducted is random and no warning is given to the AirCare contractor prior to the audit. The standard procedure followed by the auditor is as follows:

1) Arrive at centre, note the wait time indicated on the sign at the station entrance, call the AirCare hotline to determine the reported wait time and count the number of vehicles in each queue. All of the wait time data should be consistent and accurate.

2) Test the audit vehicle in each lane, waiting in the queue in the same way that a regular customer would. This provides another measure of wait time. Upon entry to the station, data entry and the gas cap test are performed as normal. Occasionally, the auditor will substitute a known failing cap or "Master" pass or fail caps to verify the accuracy of the gas cap testing equipment.

3) At the dynamometer position, an "EMS Audit" will be performed on the ASM testing equipment. This audit involves the use of a tailpipe simulator and a cylinder of calibration gas. Calibration gases are purchased from Scott Specialty Gases of Plumsteadville, PA. The gas purchased for auditing purposes has a stated accuracy of ±1%, traceable to NIST (National Institute for Science and Technology) standards. NIST is the North American reference for materials such as calibration gas and can be considered absolutely accurate. The tailpipe probe is inserted in the simulator and gas is sampled from the cylinder. The indicated readings are compared to the certified values on the cylinder label. If the indicated readings from the analyzers deviate by more than ±5% from the stated cylinder concentrations, the EMS system is re-calibrated and the check done again. If the reading does not fall within the allowable tolerance after calibration, the lane is locked out from use until maintenance has been performed and the audit has passed. Cylinder concentrations of HC, CO, CO_2 and NO_x are chosen to be representative of the vehicles being tested and are varied throughout the year in order to confirm the accuracy of the gas analysis equipment over its full operating range.

As a rule, audit gases are chosen so that they test the equipment accuracy in the area of the pass/fail standards where any inaccuracy would have the biggest impact on test outcomes.

4) After the EMS audit is complete, the audit vehicle is run through an ASM/Idle test. Using a scan tool, data are collected from the audit vehicle's on-board computer to assess the amount of load being applied by the dynamometer. Parameters such as throttle position, MAP sensor value, and Calculated Load are used to determine that the load applied is consistent across all lanes and centres. Significant deviations from normal readings suggest a fault with the dynamometer load application and result in the lane being shut down until corrective maintenance is performed.

5) Checking of the IM240 analytical equipment is done in a different way. In this test, a known amount of propane is injected at the system inlet. The calculated mass of propane determined from the measured sample volume and the dilute HC reading from the lane analyzer, is compared to the known mass of propane injected. Agreement within 3% is necessary before lane operation is permitted. The propane injection procedure confirms the accuracy of the Constant Volume Sampler flow rate and the hydrocarbon analyzer. Additional checks beyond those already required by the calibration and maintenance requirements for the IM240 test are likely unnecessary. The procedure used thus far by PVTT has been to subject the audit vehicle to a full-duration IM240 test in each lane and to evaluate the consistency of results achieved in all lanes. This method has proven effective in that the test results for the audit vehicles have been consistent and have suggested that the test apparatus is working properly. In order to evaluate the accuracy of dynamometer loading under transient operating conditions, data stream information has been downloaded during testing. The objective is to determine an acceptable range of critical parameters for the purpose of identifying potential malfunctions. As in the case of the analytical equipment, however, the fundamental requirements for dynamometer coastdown testing and calibration make it very unlikely that the units could be operating out of range.

6) Once the functional tests are complete, a visual audit of station cleanliness and upkeep is done.

7) The auditor writes a monthly report outlining the results of each station audit on a lane-by-lane basis. Any deficiencies are noted along with any known corrective action. Outstanding issues are flagged with the expectation that the AirCare contractor will correct them in short order.

In 2001, there were 452 inspection centre audits conducted as shown in Table 4.

The numbers in brackets indicate that a problem was detected during the month at that facility. In 2001, there were 11 problems identified during functional testing of the lane equipment. 7 cases involved problems with the gas analyzers. These problems were normally corrected by re-calibrating the units. There were 3 instances of out-of-range dynamometer load application and one problem detected with the diesel opacity meter.

Table 4. Number of Audits and Failures in 2001

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	(Fail)
1	0	4	4(1)	4(1)	4	4	4	4	4	4	4	4	44	2
2	0	4	4(1)	1(1)	8(1)	4	4	4	4	4	4	4	45	3
3	0	4	4	4(2)	4	4	4	4	4	4	4	4	44	2
4	0	3	3	0	6	3	3	3	0	3	3	0	27	0
5	0	5	5	4	5	5	5	5	5	5	5	5	54	0
6	0	4	4	0	8	4	4	0	4	4	4	4	40	0
7	0	2	2	2(1)	2	2	2	2	2	2	2	2	22	1
8	0	3	3	3	3	3	3	3	3	3	3	3	33	0
9	0	0	6	0	6(1)	3	3	3	3	3	3	3	33	1
10	0	3	3	3	3	3	3	3	3	3(1)	3	3	33	1
11	0	2	2	2	2	2	2	2	2(1)	2	2	2	22	1
12	0	5	5	5	5	5	5	0	10	5	5	5	55	0
Totals	**0**	**39**	**45(2)**	**28(5)**	**56(2)**	**42**	**42**	**33**	**44(1)**	**42(1)**	**42**	**39**	**452**	**11**

In 2002, there were 508 audits performed and 3 problems identified as shown in Table 5. There were zero problems identified with the gas analyzers, 1 problem with the gas cap tester, one dynamometer load problem and one problem with an opacity meter.

Table 5. Number of Audits and Failures in 2002

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Fail
1	4	4	4	4	0	4	8	4	4	4	4	4	48	0
2	4	4	4	4	4	4	4	4	4	4	4	4	48	0
3	4	4	4	4	4	4	4	4	4	4	4	4	48	0
4	6	3	3	3	6	0	6	3	0	6	3	3	42	0
5	5	5	5(1)	5	6	5	5	5	0	10	5	5	60	1
6	4	4	4	4	4	4	4	0	4	4	8	4	48	0
7	2	2	2	2	2	2(1)	2	2	2	2	2	2(1)	24	2
8	3	3	3	3	3	3	3	3	3	3	3	3	36	0
9	3	3	3	3	3	3	3	0	3	6	3	3	36	0
10	3	3	3	3	3	0	6	0	6	3	3	3	36	0
11	2	2	2	2	2	0	2	0	4	2	0	4	22	0
12	5	5	5	5	5	5	5	0	10	5	3	7	60	0
Totals	**45**	**42**	**42(1)**	**42**	**41**	**34(1)**	**52**	**25**	**44**	**53**	**42**	**46(1)**	**508**	**3**

In 2002, the audit vehicle was changed from a 1993 Dodge Caravan to a 2002 Ford Ranger. The Caravan was used for 45 ASM tests and 52 IM240 tests. Once the Ranger was put into service, it was used for 216 ASM tests and 218 IM240 tests.

From the audit results, it appears that the AirCare contractor is doing a good job of maintaining and calibrating the test equipment. This leads to a high degree of confidence in the accuracy of the emission readings supplied to vehicle owners.

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6.0 REPAIR INDUSTRY

6.1 CHANGES EFFECTIVE WITH AIRCARE II

Since the initial planning phase for a Vancouver regional vehicle inspection and maintenance program back in the 1980s, the important role of the repair industry has been a prime consideration. In order to maximize the benefits of the program, emphasis was placed on training and monitoring the repair industry to improve diagnostic skills and to gather information on the types and cost of repairs necessary to achieve meaningful emission reductions.

With the advent of AirCare II and the introduction of IM240 testing, there were concerns about the ability of the repair industry to adapt to the new test and to successfully repair vehicles to pass the re-inspection. As mentioned previously, the IM240 test is a more rigorous test of a vehicle's emission control system and, although the vehicle-specific diagnostic procedures are independent of the type of inspection, passing an IM240 test on re-inspection requires that a thorough repair be performed.

Recognizing the challenge facing the repair industry in adapting to the IM240 test, the Program Administration Office convened a Repair Advisory Committee (RAC) approximately one year in advance of program changeover to provide liaison between the program and the repair industry. The committee consisted of 13 Members representing new car dealers, franchise repair operation and independent shops. In particular, the RAC was intended to provide a means of communication to the industry as well as a forum for soliciting ideas and input from an industry perspective. The RAC was charged with investigating a number of issues that had not been addressed or had been contentious throughout the first seven years of the program, specifically:

- implementation of a fee-for-service for AirCare technicians and repair facilities;
- reviewing the minimum equipment requirements for AirCare certification;
- signage and imprinter contractor provisions;
- training course enhancements; and,
- reviewing/revising the Repair Cost Limits.

After 6 meetings, the RAC endorsed the following proposed changes to the program:

- certification fees of $75.00 and $300.00 for initial certification of technicians and repair facilities respectively;
- certification fees of $50.00 and $150.00 for re-certification of technicians and repair facilities respectively;
- additional requirements for repair centres to have a personal computer an Internet access;
- increased Repair Cost Limits; and,
- training curriculum changes to reflect new vehicle emissions control technology and changes to the inspection test procedures.

With the exception of certification fees, all changes endorsed by the RAC were implemented by January 1, 2002. The Translink Board did not approve the introduction of certification fees.

During discussions with the RAC, PVTT staff made a conscious decision to provide AirCare technicians and repair centres the ability to access data deemed critical to successful repairs to vehicles that failed the inspection. This decision led to the design, development and implementation of a web-based application called the RepairNet.

6.1.1 REPAIRNET

The RepairNet, an Internet-based application, is the result of the repair industry's desire for more detailed inspection results, the AirCare program administration's desire to improve the data collection process, and the shared goal of improving the effectiveness of certified repairs.

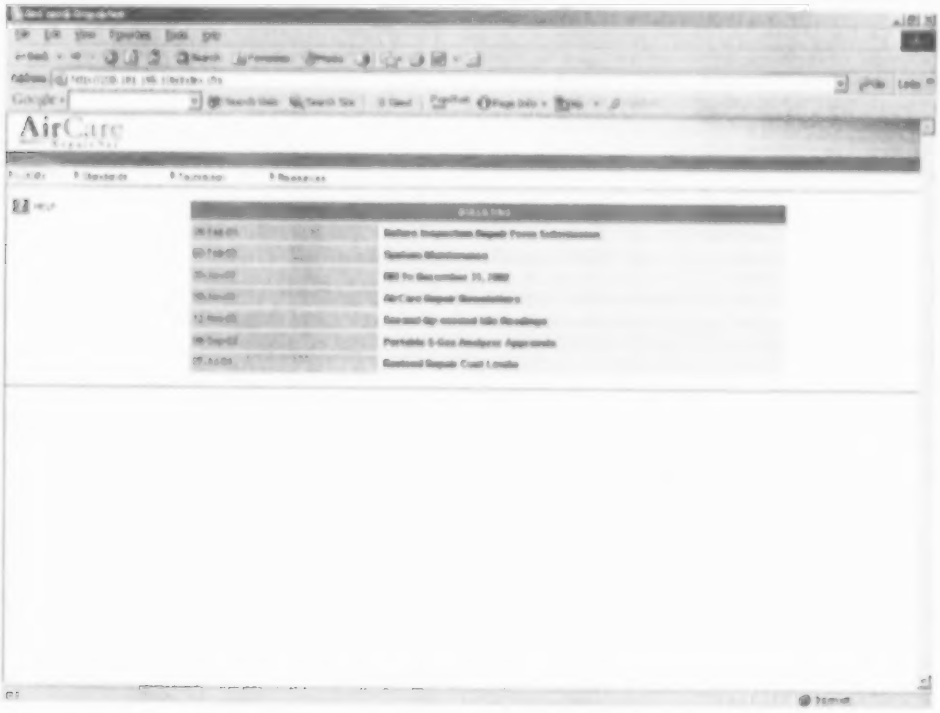

Figure 50. Front Page of the AirCare RepairNet

Prior to September 1, 2000, AirCare repair technicians choosing to submit repair data were required to manually check off 34 items on a pre-printed Repair Data Form (RDF). This form was then turned in to the inspection centre at the time of re-inspection, allowing the test to be designated as a re-test and creating the eligibility for a conditional pass. The RDF was then forwarded to AirCare head office, where the information would be manually entered into an electronic database. This allowed the program to monitor the performance of repair facilities and technicians and to track the types of repairs being performed. However, this manual process was time consuming for the administration office, which had to keypunch and then file up to several thousand RDF's every month. In addition to the difficulties imposed by such a volume of paper, the time lag associated with data entry often meant that PVTT staff could not access repair data until up to a week or more after the re-inspection had taken place.

The paper-based system also limited the amount of information that could be provided to repair technicians from the inspection lanes. The only inspection data available to technicians was whatever was printed on the inspection report. This did not provide the technician with information such as previous inspection history (unless the paper copies were kept), types of repairs and/or components replaced in previous repairs or other things that would be helpful to know.

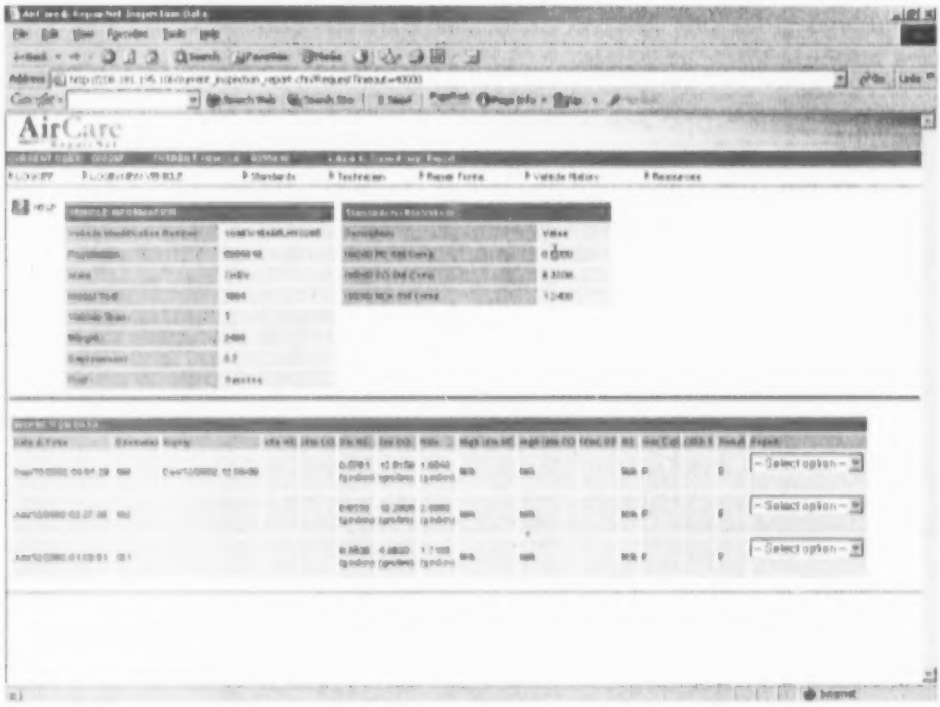

Figure 51. Vehicle Inspection History Provided by RepairNet

Internet technology allows for a significantly improved process that saves time, paper burden and provides the technician with detailed inspection results, inspection and repair histories. The end result is called the AirCare RepairNet. It provides technicians with more information to assist them in their diagnosis as well as a more streamlined process for recording the details of the repair.

Some of the functions of the RepairNet include:

- Password protection
- Access to newsletters, manuals and bulletins.
- Interactive communication through technician discussion forum and e-mail.
- Provision of a calculator to calculate the efficiency of catalytic converters.
- Access to a vehicle's current inspection results and its repair and inspection histories.
- Access to diagnostic information like graphs and second-by-second emission tables.
- Technician ability to change password and mailing address

- Access to the user's vehicle repaired history and the Repair Effectiveness Index (repair monitoring system).
- Ability to submit Vehicle Repair Forms and Before Inspection Repair Data.

To date, the RepairNet has been well received by the industry. The RepairNet delivers on its goal of providing technicians with valuable vehicle information and has streamlined the AirCare program's ability to gather and interpret inspection and repair data.

The Uniform Resource Locator (URL) is http://repairnet.aircare.ca

6.1.2 Increased Repair Cost Limits

The repair cost limits are frequently cited by the repair industry as an impediment to their performance. Since vehicle owners have the option of refusing repairs that would push the total cost above the applicable repair cost limit, technicians are prevented from making effective repairs in those cases. Given that their proficiency is judged on the basis of how many vehicles they repair and how much they reduce the emissions as a result, the inability to complete repairs on a portion of the vehicles means that their REI is compromised by program policy and is not solely determined by their skill at emissions repairs.

In an attempt to address these concerns, the repair cost limits were revised on January 1, 2001 to reflect the types or repairs required to correct emissions-related failure that resulted from the more stringent test procedures. The revised Repair Cost Limits are shown in Table 1 below:

Table 6. Repair Cost Limits

Model Year	Non-Tampering	Tampering
Pre- 1975	$300	Advisory
1975 – 1987	$400	Advisory
1988 – 1992	$500	No Limit
1993 - 1998	$600	No Limit
1999 and Newer	No Limit	No Limit

Note: Tampering is defined as the removal, destruction, disconnection or modification of an emission control device or component. For AirCare purposes, only the catalytic converter is subject to inspection for tampering.

6.1.3 Revised Training Courses and Qualifying Examinations

Qualification for AirCare certification by repair technicians has always required demonstrating knowledge of emission control systems and repair techniques by writing a 3-hour examination. Technicians wishing to upgrade their skills prior to challenging the exam or those who failed to make the passing grade after writing it, are able to take training at a number of post-secondary training institutions.

The RAC recommended that the certification and re-certification examinations be revised to include new emissions control technologies such as On Board Diagnostics II. A training sub-

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The RAC recommended that the certification and re-certification examinations be revised to include new emissions control technologies such as On Board Diagnostics II. A training sub-

committee was struck to review the existing training curriculum and to make recommendations to PVTT. The recommendation made by the training sub-committee included the development of competency profiles, learning tasks, required texts and revisions to the examinations. PVTT developed the modules associated with the test procedures and program-specific information.

Several train-the-trainer sessions were held in January of 2001. Approximately 40 automotive instructors from post secondary training institutions that provide apprenticeship training for automotive technicians attended these sessions.

PVTT staff and automotive instructors developed a bank of examination questions to complement the curriculum revisions. The examination questions were then validated by a group of automotive instructors from within the program area.

The examination structure was revised from four sections to three sections. Previously, the first section of the exam consisted of twenty general questions about the AirCare program, to be answered from a handout sheet. In the revised exam, this has been deleted so that the first section now contains 100 questions pertaining to the formation of emissions in engines and the operation of emission control devices. The next two sections are optional, consisting of twenty questions each about alternative fuels (propane and natural gas) and diesel vehicles, respectively. The re-certification exam was also revised to reflect the practical aspects of diagnosing and repairing emissions defects in vehicles.

As was the case previously, there are two separate AirCare examinations. One, administered to technicians becoming AirCare certified for the first time, is called the Theory exam. The second exam is intended for technicians that have been performing emission-related repairs for at least three years and have not qualified for automatic re-certification. This exam is called the Re-certification exam.

The revised Theory examination has an initial success rate of approximately 80 percent. The Re-certification exam initial success rate is approximately 60 percent. Technicians who complete the AirCare Practical Training course and then write the Re-certification exam have a success rate of approximately 80 percent.

Given that a digital sampling oscilloscope (lab scope) was added to the list of minimum equipment requirements for AirCare repair centre certification effective January 1, 2001, PVTT staff worked closely with the various equipment suppliers to develop a basic manufacturer-specific lab scope course. In addition, PVTT and some colleges developed the competency profiles for an in-depth, advanced lab scope course that focuses on its application to automotive diagnostic procedures.

6.1.4 DIAGNOSTIC EQUIPMENT

The implementation of the IM240 test procedures provided AirCare technicians and repair centres with unique challenges in performing effective repairs to vehicles that failed the test. Some repair centres and technicians felt they were at a distinct disadvantage because their analyzer could not measure mass emissions but only volumetric concentrations.

The RAC requested that PVTT allow the use of portable exhaust gas analyzers for the purposes of repair centre certification.

With the assistance and concurrence of the equipment suppliers, PVTT prepared a specification for portable exhaust gas analyzers loosely based on the California BAR 97 standard. Suppliers of 5-gas analyzers must warrant that their products meet the performance specifications and confirmation of this claim is to be obtained by having units tested by Environment Canada's River Road Environmental Technology Centre in Ottawa.

6.2 CERTIFIED REPAIR INDUSTRY STATISTICS:

6.2.1 TECHNICIAN CERTIFICATION REQUIREMENTS

Persons applying for certification in the AirCare Program must meet the following pre-requisites:

- British Columbia Trades Qualification (BCTQ) or Certificate of Qualification in:
  - automotive mechanical repair or
  - heavy duty diesel, with three years automotive experience or
  - commercial vehicle mechanical repair

OR

- B.C. Certificate of Apprenticeship in
  - Auto electric and tune-up

Technicians possessing Inter-Provincial certificates or qualifications from other provinces are required to apply for a BCTQ at the local Provincial Apprenticeship Branch office.

Persons with Exemption Certificates issued by the Apprenticeship Branch are NOT eligible to write the AirCare certification examinations, as they do not meet the pre-requisites of the program.

6.2.2 NUMBER OF REPAIR TECHNICIANS

Table 7. AirCare Certified Technicians Summary

AirCare Technicians	As of December 31, 2001	As of December 31, 2002
Applicants	974	1,137
Certified	1,243	1,358
Logically Deleted	580	584
Rejected	540	543
Expired	1,286	1,590
Suspended/Decertified	2	7

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Since the inception of the technician certification system, the program has maintained a fairly consistent number of active certified technicians numbering about 1,200. The number of technicians that have applied for certification at one point or another is 5,250. Table 7 provides a summary of the number of AirCare technician according to certification status at year-end in both 2001 and 2002:

6.3 REPAIR CENTRES

6.3.1 REQUIREMENTS FOR CERTIFICATION

Each AirCare repair centre must have, as a minimum, all of the equipment listed below on site, operational, and well-maintained. The meters, gauges, and other items listed may be furnished either as separate units or as components of a complete system such as an engine analyzer.

- Oscilloscope or other ignition analyzer capable of displaying ignition patterns, cylinder power contributions, and square wave and injection patterns of vehicles inspected at AirCare inspection centres. The oscilloscope or ignition analyzer must have the capability to test vehicles equipped with Distributorless Ignition System (DIS)
- Ammeter
- Ohmmeter
- Voltmeter
- Tachometer
- Vacuum/pressure gauge
- Cam-angle dwell meter
- Ignition timing light, or timing light with timing advance adjustment to substitute for Distributor advance tester
- Compression test gauge
- Vacuum pump for applying simulated manifold vacuum to emission control devices
- Distributor advance tester
- Exhaust emissions analyzer and calibration gases meeting the specifications established by the province.
- Scan tool(s), supplemental analyzer provisions, or detailed reference materials sufficient to allow the extraction and interpretation of computer fault codes from any vehicle being repaired that is equipped with an exhaust oxygen sensor and malfunction indicator light
- Computer, modem, printer and an Internet Service Provider (ISP) for accessing vehicle inspection and repair information on-line*
- Labscope that meets the requirements as outlined by PVTT*

* Enhanced program requirements since September 1, 2000.

6.3.2 NUMBER OF AIRCARE CERTIFIED REPAIR FACILITIES

Effective September 1, 2000, additional requirements for certification were imposed as noted in points 14 and 15 above. It became necessary to have a computer with Internet access in order to enter repair data electronically as opposed to the previous paper-based system. Previously, a credit card imprinter was used to validate the hard copy RDF form. This imprinter was subject to a monthly rental charge that was no longer required for Repair Net. For shops that already had a computer and Internet access, the switch to an electronic system actually meant a reduction in costs.

The table below illustrates the breakdown of repair centres according to type as of December 31 of 2001 and 2002. A decrease in the number of repair shops is evident in 2002, primarily among independent shops.

Table 8. Types of Repair Centre in 2001 and 2002

Repair Centre Types	At December 31, 2001	At December 31, 2002
Independents	261	231
Franchise Operators	65	62
Dealerships	102	96
Corporate Centres	44	44
Total	**472**	**433**

6.4 REPAIR INDUSTRY PERFORMANCE

Aside from the desire to provide the public with access to a trained and well-equipped repair industry, the establishment of a certified repair industry provided an opportunity to collect information about the types of repairs performed and on the results of emissions-based diagnoses. With the implementation of RepairNet, an electronic RDF, as shown in Figure 52, was launched providing much greater flexibility in the reporting of repair actions. The new form allows data entry for 91 possible items.

For each item, there are 4 possible entries as follows:

- (R) Replaced: The item has been replaced
- (S) Repair/Cleaned/Adjusted/ Reconnected: The item has been repaired, cleaned, adjusted or reconnected
- (M) Missing: The item is noted as missing during the diagnosis
- (D) Defective, But Not Repaired: Item was too expensive to fit within the cost limit or parts were unavailable to perform the repair.

The default status of each of the 91 items is OK. Therefore only those items that were involved in the repair or diagnosed as missing or defective need to be addressed by the individual completing the form.

A fully completed RDF provides comprehensive information to the program administration office about the types and cost of repairs performed on vehicles that fail the AirCare inspection. This data will be discussed later in this section.

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Figure 52. Repair Data Form on RepairNet

6.5 RDF STATISTICS

IN 2001, there were 33,662 RDF's submitted through the RepairNet. In 2002, this number increased to 39,052. This increase is proportional to the increased number of failing vehicles in 2002. As mentioned previously, repair data is submitted on one in every three vehicles that fail.

In both 2001 and 2002, there were 1.08 RDFs submitted for every vehicle repaired at a certified AirCare repair facility, indicating that some vehicles had repair data submitted more than once. Reasons for this include resubmitting a RDF with corrected repair information on the same repair or a second-chance repair where a vehicle failed after repairs and then additional work was performed to correct the problem that was overlooked the first time.

Analysis of the data provided suggested that the top 5 items replaced during AirCare repairs were as shown in Table 9 below. In each year Pre- and Post-1992 vehicles are treated separately.

The most common "Serviced" items for older vehicles continue to be the same as in previous years. The most common items are Idle Mixture, Idle Speed, Spark Timing, Vacuum Leaks, and Other Carb/Injection.

Table 9. Top 5 "Replaced" Items in 2001 and 2002

2001		2002	
Pre-1992	1992 and Newer	Pre-1992	1992 and Newer
Oxygen Sensor	Oxygen Sensor	Oxygen Sensor	Catalytic Converter
Spark Plugs	Catalytic Converter	Catalytic Converter	Oxygen Sensor
Catalytic Converter	Spark Plugs	Spark Plugs	Spark Plugs
Air Filter	Air Filter	Air Filter	Air Filter
EGR Valve	EGR Valve	Oil Contamination	Oil Contamination

Table 10. Top 5 "Serviced" Items in 2001 and 2002

2001		2002	
Pre-1992	1992-and-Newer	Pre-1992	1992 and Newer
Idle Mixture	Combustion Deposit	Ignition Timing	Combustion Deposit
Ignition Timing	Ignition Timing	Idle Mixture	Ignition Timing
Idle Speed	Throttle Body	Idle Speed	Throttle Body
Combustion Deposit	EGR Passages	Combustion Deposit	Fuel Injector
EGR Passages	EGR System	EGR Passages	EGR Passages

The most common items remaining defective after certified repair are shown in Table 11. This data identifies repairs that were required, but not completed, usually because the cost would exceed the applicable repair cost limit. The list did not change much from 2001 to 2002. In fact, the top three items are the same in both years. Interestingly, catalytic converter was among the most common items that remained defective for all the vehicles, likely due to the high replacement cost of this item in some applications. Since aftermarket catalytic converters are available at a lower cost than OEM units, it is concerning to see a high incidence of non-replacement of defective converters. In general engine mechanical problems, most of which require partial or complete overhauling of the engine, are most often left uncorrected, once again due to the high cost involved with this type of repairs.

Table 11. Top 5 "Remaining Defective" Items in 2001 and 2002

2001		2002	
Pre-1992	1992 and Newer	Pre-1992	1992 and Newer
Catalytic Converter	Catalytic Converter	Catalytic Converter	Catalytic Converter
Carburetor	Engine Mechanical Other	Carburetor	Engine Mechanical Other
Engine Mechanical Other	Oxygen Sensor	Engine Mechanical Other	Oxygen Sensor
Compression	Compression	Compression	Combustion Deposit
Cylinder Head	Cylinder Head	Cylinder Head	Cylinder Head

6.6 COST OF REPAIRS

When completing the RDF, repair facilities are required to enter the actual cost of the repairs performed (customer's out-of-pocket charges including taxes) as well as the estimated cost of performing all of the necessary emission-related repairs.

Table 12 shows the average cost of repairs reported on RDF's in 2001 and 2002

Table 12. Average Cost of Repairs in 2001 and 2002

Calendar Year	Average Cost ($)
2001	343
2002	377

The average is not a complete indicator of the cost of repairs. Looking at the most recent data, it can be seen that many repairs involve a total cost of less than $150. A distribution of repair costs is shown in Figure 53.

One possible conclusion to be derived from the above figure is that the cost of repairing vehicles to pass the AirCare inspection is not necessarily very high. This could be viewed as a positive factor, but repairs involving a total cost of less than $150 likely include many that are not very effective. Simple repairs such as installing new spark plugs, replacing the air filter, installing a new PCV valve, and similar actions can use up available repair dollars without having much effect on emissions performance.

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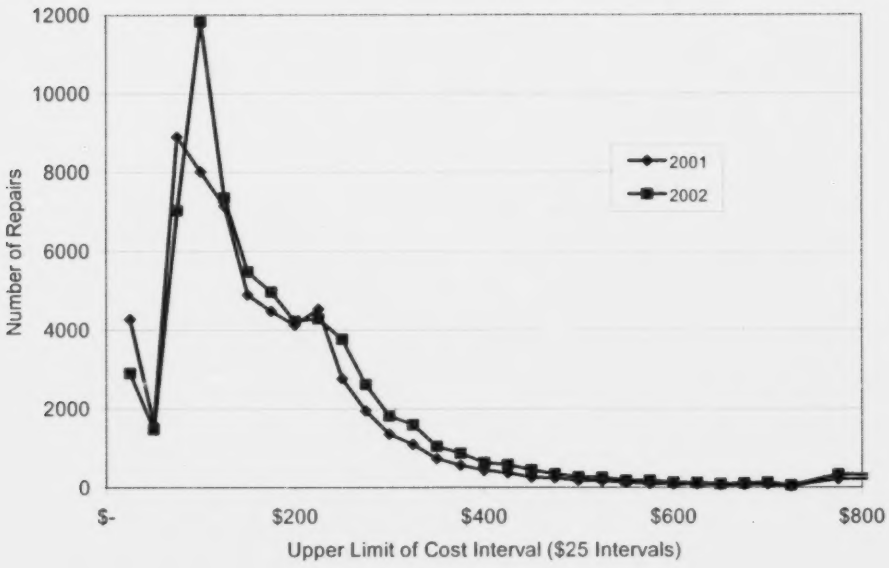

Figure 53. Repair Cost Distribution for 2001 and 2002

6.7 CERTIFIED REPAIR CONDITIONAL PASSES

The Conditional Pass was created to provide financial relief to some owners of failing vehicles. The Conditional Pass would allow the vehicle to be re-licensed so repairs could be completed over a longer time period. The concept of waivers or hardship exemptions is applied in most, if not all, other I/M programs. Usually, the issuance of a waiver requires that a minimum amount be spent attempting to bring the vehicle into compliance and that some kind of improvement in emissions be achieved. In some cases, a waiver may be granted in cases where the economic situation of the vehicle owner does not permit repairing the vehicle and denying the use of the vehicle would impose undue hardship. In the United States, the EPA requires that I/M programs maintain a waiver rate of less than 2%.

For the AirCare program, a different system was developed so that vehicle owners would be assured of at least a Conditional Pass provided that they took their vehicle to a certified AirCare facility for repairs. This provided an automatic incentive to choose a certified shop over a non-certified one. Rather than a waiver, the terminology adopted for AirCare was "Conditional Pass". There are two types of Conditional Passes – one where the vehicle cannot be repaired for less than the applicable repair cost limit, referred to as a "C" type of Conditional Pass, and another where all the needed repairs were supposedly completed, but the vehicle was still not able to pass, referred to as a "Q" type of Conditional Pass. This second form of waiver does not exist in other I/M programs, but was created because of the guarantee of at least a Conditional Pass whenever a certified repair shop does the work. It was expected during the design of the program that this form Conditional Pass would rarely be issued.

Table 13. Certified Repair Re-Inspection Results in 2001 and 2002

Result	2001		2002	
	Pre-1991	1992 & Newer	Pre-1991	1992 & Newer
Pass	17,920	3,375	15,728	9,077
Cost Waiver	3,759	511	3,429	1,548
Qualified Waiver	4,400	1,213	3,469	3,023
Total Conditional Passes	8,159	1,724	6,898	4,571
% Conditional Passes	31.3%	33.8%	30.5%	33.5%
Total	26,079	5,099	22,626	13,648

In 2001 there were a total of 9,883 Conditional Passes issued out of 31,178 certified repairs. This means that 31.7% of certified repairs were unsuccessful in making the vehicle pass re-inspection. In 2002, there were 11,469 conditional passes issued out of 36,274 certified repairs, an identical 31.6%. In both years there were more Q waivers issued than C waivers.

As with the analysis of repaired items, it was decided to treat the repairs to the pre-1992 vehicles separately from those to 1992-and-newer vehicles. The results show that the number of Q waivers is higher for the newer technology vehicles, possibly reflecting a lack of experience in repairing vehicles tested according to the IM240 test procedure.

A new policy came into effect on January 1, 2001 preventing owners of 1992-and-newer vehicles from qualifying for two years of licensing on the basis of a Conditional Pass. As a result, a distinct difference was created between a full pass of the IM240 test and a Conditional Pass. In fact, the window of opportunity for purchasing up to one year of licensing with a Conditional Pass was reduced from 363 to 90 days. This was done to prevent the unintended extension of the licensing period for vehicles that did not comply with program requirements. One scenario that was known to have occurred was one in which a vehicle owner would receive a conditional pass as a result of failing the re-inspection after certified repairs were performed. The owner would then purchase a 12-month license on the basis of the Conditional Pass and drive the vehicle for 11 months, at which time he/she would sell the vehicle. The new owner was still eligible to purchase a 12-month license and insurance policy on the vehicle because the AirCare test expiry date had not been reached, meaning that almost two years of driving could be achieved from one Conditional Pass. With the change to a 90-day period of validity, the owner of a vehicle with a Conditional Pass can still purchase up to 12 months of licensing, but after 90 days, no further re-licensing of the vehicle can occur without another AirCare inspection. In effect, the maximum period of operation has been reduced to 15 months from 23.

6.8 MODES OF FAILURE ON RE-INSPECTION

Table 14 below illustrates the modes of failure evident in re-inspections of 1991-and-older vehicles that did not achieve a pass after failing their first inspection. The table shows that the

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% Conditional Passes	31.3%	33.8%	30.5%	33.5%
Total	**26,079**	**5,099**	**22,626**	**13,648**

In 2001 there were a total of 9,883 Conditional Passes issued out of 31,178 certified repairs. This means that 31.7% of certified repairs were unsuccessful in making the vehicle pass re-inspection. In 2002, there were 11,469 conditional passes issued out of 36,274 certified repairs, an identical 31.6%. In both years there were more Q waivers issued than C waivers.

As with the analysis of repaired items, it was decided to treat the repairs to the pre-1992 vehicles separately from those to 1992-and-newer vehicles. The results show that the number of Q waivers is higher for the newer technology vehicles, possibly reflecting a lack of experience in repairing vehicles tested according to the IM240 test procedure.

A new policy came into effect on January 1, 2001 preventing owners of 1992-and-newer vehicles from qualifying for two years of licensing on the basis of a Conditional Pass. As a result, a distinct difference was created between a full pass of the IM240 test and a Conditional Pass. In fact, the window of opportunity for purchasing up to one year of licensing with a Conditional Pass was reduced from 363 to 90 days. This was done to prevent the unintended extension of the licensing period for vehicles that did not comply with program requirements. One scenario that was known to have occurred was one in which a vehicle owner would receive a conditional pass as a result of failing the re-inspection after certified repairs were performed. The owner would then purchase a 12-month license on the basis of the Conditional Pass and drive the vehicle for 11 months, at which time he/she would sell the vehicle. The new owner was still eligible to purchase a 12-month license and insurance policy on the vehicle because the AirCare test expiry date had not been reached, meaning that almost two years of driving could be achieved from one Conditional Pass. With the change to a 90-day period of validity, the owner of a vehicle with a Conditional Pass can still purchase up to 12 months of licensing, but after 90 days, no further re-licensing of the vehicle can occur without another AirCare inspection. In effect, the maximum period of operation has been reduced to 15 months from 23.

6.8 MODES OF FAILURE ON RE-INSPECTION

Table 14 below illustrates the modes of failure evident in re-inspections of 1991-and-older vehicles that did not achieve a pass after failing their first inspection. The table shows that the

number of HC, CO and NO_x failures is about equal. For idle tests, HC failures are twice as likely as CO failures.

Table 14. Certified Repair Re-Inspection Failure Modes for Pre-1992 Vehicles

Failures Mode	2001	2002
ASM HC	2,564	2,110
ASM CO	3,015	2,335
ASM NO_x	2,651	2,001
Idle HC	2,330	2,518
Idle CO	1,149	1,074

Table 15 shows the similar failure modes for 1992-and-newer vehicles. NO_x emission was the most common mode of failure in both 2001 and 2002. However, the proportion of HC failures increased significantly in 2002, becoming almost as common as NO_x failures. CO failures occurred at about half the rate of HC or NO_x.

Table 15. Certified Repair Re-Inspection Failure Modes for 1992 and Newer Vehicles

Failures Mode	2001	2002
HC	890	2,415
CO	498	1,301
NO_x	1,001	2,497

Table 16 shows the re-inspection results for diesel vehicles according to age group for those vehicles that went to certified AirCare repair facilities. Most of the failures and, consequently, the re-inspections occurred in the older age group. Almost all of the 1992-and-newer diesel vehicles were successfully repaired in 2001 and 2002. However, 30% of the pre-1992 diesel vehicles failed the re-inspection in 2001. The success rate improved in 2002, with only 20% of pre-1992 diesel vehicles still failing after certified repairs.

Table 16. Certified Repair Diesel Re-Inspection Results in 2001 and 2002

Opacity Result	2001		2002	
	Pre-1992	1992 & Newer	Pre-1992	1992 & Newer
Pass	89	11	59	16
Fail	39	1	14	1

6.9 REPAIR EFFECTIVENESS INDEX

Although the effectiveness of AirCare-related repairs is discussed elsewhere in this report, the AirCare program administration has, since 1995, calculated a Repair Effectiveness Index (REI) for each certified repair.

The REI is a dimensionless index with potential values ranging from minus one to plus one. The index is based on the magnitude of the reduction in emission readings achieved for the post-repair test compared to the pre-repair inspection. It also compares the after-repair results to observed "good" results for that type of vehicle and provides additional credit for repairs that restore vehicles as closely as possible to their potential for low emissions. A third factor relates to the logic of the diagnostic conclusion. These factors are calculated for each inspection mode and for each pollutant. The three factors are weighted so that the greatest emphasis is on emission reductions attributable to the repair.

By design, an REI of 0 will occur if the readings noted after repair are essentially the same as they were before. This reflects a benign repair in which no benefits were evident. Conversely, an REI of plus one would correspond to reducing a vehicle's emissions from very high levels across the board to essentially zero across the board. A minus 1 would reflect the opposite situation in which the repairs cause the vehicle's emissions to increase dramatically to maximum measured values across the board.

In practice, REI values greater than 0.8 are virtually never achieved. Negative REI's are also rare. REI's in the positive region indicate that repairs are effective in reducing emissions. The table below shows the average REI for the repair industry as a whole in 2000 (AirCare I), compared to 2001 and 2002 (AirCare II).

Table 17. Average REI in 2001 and 2002

Year	Average REI
2000	0.37
2001	0.41
2002	0.40

The apparent improvement in REI was caused by a shift in the calculation resulting from the introduction of the IM240 test and the use of a reporting method that produced very low re-inspection results in the event of a fast-pass result. The EPA "fast pass" algorithm divided the cumulative grams of HC, CO and NO_x at the point of fast-pass (any point between 30 seconds and 239 seconds) by the theoretical IM240 test distance of 3.152 km. This calculation method would produce artificially low emissions readings on fast-pass tests (at the 30-second point, the actual distance travelled is only 0.186 km, meaning that the g/km result is $1/17^{th}$ of the actual g/km reading. Considering that all failing tests run full duration, the comparison of any failed result with a fast-pass re-inspection result gives the impression of a very significant emission reduction. In 2002, this situation was effectively resolved by devising a new way of reporting the emission results of fast-pass inspections. Rather than dividing the actual mass of emissions by the total test length, the result was based on a proportion of the pass/fail limit, the proportioning factor being based on the time required to achieve a fast pass. The basic premise was that the longer a vehicle takes to achieve a fast pass, the more marginal its emissions performance. This calculation method relies on the proportion of the measured grams of each pollutant

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divided by the fast pass standard multiplied by the full-duration (Composite) standard. Thus, the reported result will always be some fraction of the Composite standard, with at least one of the results being fairly close to the limit if the fast-pass occurred late in the test.

The REI for 2002 takes into account the enhancements made to the "fast pass" algorithm. It should also be noted that there were no material changes to the actual REI algorithms in either 2001 or 2002.

The REI seems to provide a reliable means of ranking repair quality. Technicians that had a good reputation for successfully fixing vehicles prior to the introduction of the REI system have tended to maintain high REI averages. Conversely, technicians with low average REI's tend to show weaknesses in their understanding of how to diagnose and repair vehicles with high emissions. REI is also used to determine eligibility for Quality Repair Awards, which are awarded every 3 months to technicians with high numbers of repairs and the highest average REIs for the quarter. 101 individual technicians have received at least one Quality Repair Award. Most (77) have only received one award, but many have received more, with one technician receiving ten.

PVTT staff has actively used the REI to as an indicator of sub-standard technician and facility performance. All repairs performed by apparent poor performers are reviewed to establish if further action is required to correct this sub-standard performance and ensure an acceptable quality of diagnosis and repair to the motoring public. It is important that this be done because all AirCare certified repair centres are listed for motorists without regard to the REI level of the facility. In essence, one should be as good as any other. In reality, however, this is not usually the case but every effort needs to be made to ensure that a minimum level of proficiency is maintained.

The Office of the Superintendent of Motor Vehicles (OSMV) has jurisdiction over the Motor Vehicle Act and Regulations and has the authority to de-certify technicians or facilities for cause when other attempts to remedy problem situations have failed. In a recent Show Cause Hearing, the Superintendent's decision confirmed that the REI is an objective monitoring tool for technicians and repair facilities.

6.10 CONSUMER PROTECTION AND DISPUTE RESOLUTION

One of the associated responsibilities of providing a certified repair industry is that the public expects to be protected from unscrupulous repair shops and to have their complaints dealt with on their behalf by program administrators.

Given the thousands of repairs performed in response to failed AirCare inspections, there have been relatively few complaints received. When a customer calls with a complaint, the first action is to ask whether they have advised the repair facility of the problem. Business owners have a vested interest in ensuring that their customers are satisfied and will normally take the necessary action to resolve their concerns. In most cases, getting the two parties to talk to one another about the problem results in a solution and nothing further is heard about the matter.

If, however, the vehicle owner and the repair facility fail to resolve the issue, the AirCare program administration may become involved. In order to resolve the situation, it is necessary to examine the vehicle to determine why it is unable to pass the test and what would be needed

to bring the vehicle into compliance. To initiate this process, the vehicle owner must agree to supply their vehicle to the administration office for a detailed examination by staff technicians.

The investigation usually begins with a full FTP test of the vehicle in question. This is an important step, because it establishes the vehicle's emissions output relative to the standards it was designed to meet. If the vehicle fails the FTP test by exhibiting emissions above the standards to which it was designed, it can be concluded that some sort of emission related defect persists in the vehicle, despite the repair efforts already undertaken.

Once the FTP test has been completed, an AirCare staff member who is a qualified automotive technician will perform a thorough diagnosis of the engine and emission control system. This diagnostic procedure is identical to the one that should be used by any certified shop when diagnosing an emissions problem. Any deficiencies identified during the diagnostic check are recorded on a worksheet. Printouts of readings from diagnostic equipment are also produced as evidence. After completing the diagnosis, a verbal explanation is given to the vehicle owner, supplemented by a complete written description sent by mail to both the repair shop and the vehicle owner within 5 working days of the examination.

If the analysis by AirCare staff indicates problems that were overlooked by the certified repair shop, it is expected that these repairs will be completed. Similarly, if there was work performed by the certified repair shop that did not appear to be justified, it will be recommended that some sort of restitution be made. Usually, the cost of the needed work is reduced by the amount of any compensatory amount. In most cases, the vehicle ends up passing the test and the situation is resolved. At the very least, the customer is made aware of the reason that their vehicle did not pass the test and what work needs to be done

In 2001, there were 14 instances in which FTP testing and diagnosis by AirCare staff was needed to resolve a repair dispute. In 2002, the number was 15.

7.0 EVALUATING EMISSIONS REDUCTIONS

7.1 MASS EMISSION SAMPLES

7.1.1 MES3 AND MES4 DATA COLLECTION

As mentioned previously, mass emission data have always been used to calculate program benefits as opposed to comparing before and after emission results from volumetric test data. These data were obtained from am a separate test program in which failing vehicles were tested in the AirCare Research Centre according to the HOT 505 test procedure. Due to the logistics involved in obtaining and testing vehicles for this program, it was impossible to do more than 6 per day, and, in practice, the total number of tests generated annually was much less than one thousand.

The procedures used to collect and process data for Mass Emission Sample Three (MES3) were the same as those used for MES1 and MES2, and were fully described in the AirCare Eight Year Report. Vehicles that failed their initial test were volunteered for testing by owners in exchange for a re-inspection coupon and a gasoline voucher. They were tested using the HOT 505 procedure in the AirCare Research Centre, before being repaired, and again after being repaired. Two characteristics of MES3 (as well as of MES1 and MES2) are that it is a relatively small sample, and that it only comprises vehicles that have failed inspection.

The data contained in MES3 was collected from January 2001 to June 2002. Four hundred vehicles with before and after test results are represented by this sample.

Changing the inspection procedure to IM240 for newer vehicles provided an opportunity to collect mass-emission sample data directly in the inspection lanes. The inspection data itself is not usable as mass-emission sample data, because the various different ways to pass the test mean that the reported results do not necessarily represent what the mass-emissions would be if the vehicle was subjected to the full 240-second cycle. The fast-pass provisions actually mean that the only vehicles that normally go full duration are those which fail. To collect data for Mass Emission Samples that would contain the appropriate proportion of passing vehicles, it was decided to select 8000 vehicles per year for full-duration IM240 testing. Vehicles were not selected randomly, but the objective was to obtain a representative cross-section of the active in-use fleet. Sample testing was enabled only when wait times were short and if the vehicle being tested met pre-established criteria pertaining to model year, make and vehicle type. These criteria are supplied in a matrix from the program administrator to the contractor. The requirement to perform sample testing will continue to the end of the current contract, so it will also furnish data for MES5 (2003-4) and MES6 (2004-6).

The full-duration IM 240 sample includes vehicles back to model year 1957. Normally, any 1991-or-older vehicle is only subject to ASM2525+idle for actual inspection compliance, so the sample includes many vehicles which do not normally receive an IM240 inspection. In fact, any vehicle selected for the sample first receives its ordinary inspection, and the sample testing is done afterwards. This eliminates any possibility of the sample test influencing the ordinary inspection. It also establishes some degree of standardized preconditioning for the sample tests.

The make-up of the full-duration IM 240 sample is controlled by the Program Administration Office. It is intended to reflect the profile of the in-use light-duty fleet, and can be varied by vehicle type, model year, engine size, and make. It is possible to select very specific groups of vehicles if we desire to focus attention on such a group for a defined purpose. In the inspection lanes, sample vehicles are selected automatically by the lane software which takes into account how busy the lane is (from wait-time data) and compares the vehicle specifications to the sample definition. Once a vehicle is matched and selected, the required quota for that sample group is decremented. The selection decision is made when the vehicle first arrives, before inspection, and because most vehicles pass inspection it means that most of those in the sample pass. For these vehicles, the sample test just adds a few minutes to the time spent getting an annual or biennial inspection, and many owners do not even realize that a sample test has been conducted as well as the ordinary inspection procedure. But if a selected vehicle fails inspection, it is tagged to receive a sample test each time it comes back for re-inspection, until it finally satisfies program requirements by getting a pass or conditional pass. Any failed inspection already takes much longer than the average passed inspection, and adding the 240-second sample test each time can be very noticeable. However, regulations require that if a vehicle is selected, the owner must allow the test to be conducted. Inspection results are only printed and validated for licensing after the sample test has been completed. If the sample test is not completed the inspection is not valid.

MES4 contains test data from 8,872 initial inspections. Of these 7,986 were passing, and 886 failed. There were 766 re-inspection tests on vehicles that had been repaired.

7.1.2 MES4 Stratification

The emission factors derived from the mass emission sample were stratified to match the mass emission reduction calculation. The stratification was made according to age group, and pass/fail mode. 1992-and-newer vehicles were also stratified by vehicle type. Overall, there were seven age groups identified based predominantly on emission control technology level. These were: pre-1972 (little or no emission control); 1972-1981 (engine controls/early generation catalytic converter); 1982-1987 (Canadian re-calibrated and U.S. Tier 0); 1988-1991 (Tier 0); 1992-1995 (Tier 0 and some Tier 1); 1996-2000 (Tier 1); 2001 and newer (Tier 1, NLEV). For pre-1992 vehicles that receive an ASM+idle inspection, there are 31 possible failure modes, but only the six most common in each age group have been considered individually. These six modes cover 75% of all failures. The other modes have been treated simply as 'other'. The 1992-and-newer vehicles, subject to IM240 inspection, have only seven possible failure modes, and all have been considered separately.

7.1.3 Failure Modes

The incidence of the most common failure modes during 2002 is shown in Table 18 to Table 25. For all ages back to the 1972 model year, NO_x emissions stands out as the most common failure mode for both passenger cars and trucks. Pre-1972 vehicles were not built with any consideration for controlling NO_x emissions, so they are only subject to an extremely lenient inspection standard for NO_x and they rarely fail.

Table 18 to Table 21 show the failure modes for 1991-and-older vehicles. The ASM/Idle test includes pass/fail criteria for 2 pollutants at idle and 3 pollutant measurements under steady-state operation. In the tables, the outcome of the test is described as a series of P's and/or F's corresponding to the test mode and pollutant type as follows: 1) Idle HC; 2) Idle CO; 3); ASM

HC; 4) ASM CO; 5) ASM NO_x. Therefore, FFPFP refers to a failure of both HC and CO at idle and failure for CO only on the ASM test. Although these five measurements can generate 32 different combinations, only the top six failure modes are shown.

Table 18. Failure Modes of All Pre-1972 Vehicles

All Pre-1972 Vehicles		
Modal Emission Results	Number of Inspections	% of Total
FFPFP	204	2.04%
FFPPP	344	3.44%
PFPFP	561	5.61%
FPPPP	663	6.63%
PPPFP	740	7.41%
PFPPP	1,154	11.55%
PPPPP	5,271	52.75%
% of Failures in Top Six Failure Modes		77.64%
Total	9,993	

Table 19. Failure Modes of All 1972-1981 Vehicles

All 1972-1981 Vehicles		
Modal Emission Results	Number of Inspections	% of Total
PFPFP	734	1.57%
FFPPP	918	1.97%
PFPPP	1,863	3.99%
PPPPF	1,888	4.04%
PPPFP	2,749	5.89%
FPPPP	3,021	6.47%
PPPPP	31,659	67.80%
% of Failures in Top Six Failure Modes		74.30%
Total	46,697	

Table 20. Failure Modes of All 1982-1987 Vehicles

All 1982-1987 Vehicles		
Modal Emission Results	Number of Inspections	% of Total
FFPPP	1,657	1.10%
PPFFP	1,771	1.18%
PFPPP	2,201	1.47%
FPPPP	5,631	3.75%
PPPFP	5,962	3.97%
PPPPF	9,258	6.16%
PPPPP	115,343	76.79%
% of Failures in Top Six Failure Modes		75.95%
Total	150,209	

Table 21. Failure Modes of All 1988-1991 Vehicles

All 1988-1991 Vehicles		
Modal Emission Results	Number of Inspections	% of Total
FPFPP	2,681	0.97%
PPFPP	3,282	1.18%
FFPPP	3,463	1.25%
FFFFP	4,165	1.50%
FPPPP	8,257	2.98%
PPPPF	11,907	4.30%
PPPPP	226,940	81.90%
% of Failures in Top Six Failure Modes		67.31%
Total	277,087	

Table 22 to Table 25 show the failure modes for 1992-and-newer vehicles.

The IM240 test measures only three emissions, thus the modal emission result is in the order: 1) HC; 2) CO; 3) NO_x. There are only 8 combinations that can be created by three emissions and therefore they are all listed in the table. The tables are also broken down by the types of vehicles: Passenger Cars and Trucks; and separated by model years: "1992 to 1995" and "1996 and Newer". Overall, the most common failure mode for 1992 and newer vehicles was for NO_x-Only.

Table 22. Failure Modes of 1992-1995 Passenger Cars

1992-1995 Passenger Cars		
Modal Emission Results	Number of Inspections	% of Total
PFF	132	0.20%
FFF	712	1.10%
PFP	758	1.17%
FPF	2,555	3.96%
FFP	2,768	4.29%
FPP	4,327	6.70%
PPF	4,425	6.86%
PPP	48,869	75.71%
Total	654,546	

Table 23. Failure Modes of 1996 and Newer Passenger Cars

1996 and Newer Passenger Cars		
Modal Emission Results	Number of Inspections	% of Total
PFF	68	0.04%
FFF	287	0.17%
FPF	1,068	0.62%
FFP	1,595	0.92%
PFP	1,912	1.11%
PPF	2,065	1.20%
FPP	2,400	1.39%
PPP	163,288	94.56%
Total	172,683	

Table 24. Failure Modes of 1992-1995 Trucks

1992-1995 Trucks		
Modal Emission Results	Number of Inspections	% of Total
PFF	198	0.55%
FFF	346	0.97%
FPF	914	2.55%
PFP	984	2.75%
FPP	1,291	3.60%
FFP	1,453	4.06%
PPF	4,774	13.33%
PPP	25,862	72.20%
Total	35,822	

Table 25. Failure Modes of 1996 and Newer Trucks

1996 and Newer Trucks		
Modal Emission Results	Number of Inspections	% of Total
PFF	460	0.35%
PFP	1,216	0.92%
FFF	1,798	1.36%
FPP	2,150	1.62%
FFP	2,189	1.65%
FPF	2,228	1.68%
PPF	8,231	6.21%
PPP	114,354	86.22%
Total	132,626	

7.1.4 MES4 IM240 Emission Factors

Emission factors were derived for all the stratifications described earlier, for cases where the initial test result was either pass or fail and for re-inspections where the repairs were judged to be either effective or ineffective, based on the proximity of the post-repair test result to the average for passing vehicles. Because MES4 is much bigger than previous mass emission samples, very little interpolation was required to populate all parts of the emission factor matrix. By far the biggest increase in strata sample sizes was for vehicles that passed, because most of

HC; 4) ASM CO; 5) ASM NO_x. Therefore, FFPFP refers to a failure of both HC and CO at idle and failure for CO only on the ASM test. Although these five measurements can generate 32 different combinations, only the top six failure modes are shown.

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Modal Emission Results	**Number of Inspections**	**% of Total**
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% of Failures in Top Six Failure Modes		77.64%
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% of Failures in Top Six Failure Modes		74.30%
Total	**46,697**	

Table 20. Failure Modes of All 1982-1987 Vehicles

All 1982-1987 Vehicles		
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PPFFP	1,771	1.18%
PFPPP	2,201	1.47%
FPPPP	5,631	3.75%
PPPFP	5,962	3.97%
PPPPF	9,258	6.16%
PPPPP	115,343	76.79%
% of Failures in Top Six Failure Modes		75.95%
Total	**150,209**	

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PPPPP	226,940	81.90%
% of Failures in Top Six Failure Modes		67.31%
Total	**277,087**	

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FPP	4,327	6.70%
PPF	4,425	6.86%
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Total	654,546	

Table 23. Failure Modes of 1996 and Newer Passenger Cars

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Modal Emission Results	Number of Inspections	% of Total
PFF	68	0.04%
FFF	287	0.17%
FPF	1,068	0.62%
FFP	1,595	0.92%
PFP	1,912	1.11%
PPF	2,065	1.20%
FPP	2,400	1.39%
PPP	163,288	94.56%
Total	172,683	

Table 24. Failure Modes of 1992-1995 Trucks

1992-1995 Trucks		
Modal Emission Results	Number of Inspections	% of Total
PFF	198	0.55%
FFF	346	0.97%
FPF	914	2.55%
PFP	984	2.75%
FPP	1,291	3.60%
FFP	1,453	4.06%
PPF	4,774	13.33%
PPP	25,862	72.20%
Total	35,822	

Table 25. Failure Modes of 1996 and Newer Trucks

1996 and Newer Trucks		
Modal Emission Results	Number of Inspections	% of Total
PFF	460	0.35%
PFP	1,216	0.92%
FFF	1,798	1.36%
FPP	2,150	1.62%
FFP	2,189	1.65%
FPF	2,228	1.68%
PPF	8,231	6.21%
PPP	114,354	86.22%
Total	132,626	

7.1.4 MES4 IM240 Emission Factors

Emission factors were derived for all the stratifications described earlier, for cases where the initial test result was either pass or fail and for re-inspections where the repairs were judged to be either effective or ineffective, based on the proximity of the post-repair test result to the average for passing vehicles. Because MES4 is much bigger than previous mass emission samples, very little interpolation was required to populate all parts of the emission factor matrix. By far the biggest increase in strata sample sizes was for vehicles that passed, because most of

MES4 consists of this type of data. This has massively improved the reliability of the emission factors for passing vehicles, and because they account for most of the fleet, it also greatly improves the reliability of the overall fleet mass emission model and the emission reduction calculation.

Table 26 shows the average emission results for passing and failing vehicles taken from the full-duration mass emission sample. These are aggregated back to the level of vehicle type, age group, and initial versus repaired condition, without showing the detail of individual failure modes and effective versus ineffective repairs.

Table 26. MES4 IM240 Emission Factor Summary

			INITIAL CONDITION				AFTER REPAIR			
Vehicle Type	Age Group	Result	Sample Size	Average Readings (g/km)			Sample Size	Average Readings (g/km)		
				HC	CO	NOx		HC	CO	NOx
All	pre-1972	Pass	32	2.6	19.2	2.1				
		Fail	21	4.6	39.6	2.3	17	3.8	37.0	1.8
All	1972-1981	Pass	283	1.4	13.0	2.6				
		Fail	70	3.1	23.0	3.0	43	1.5	14.0	2.1
All	1982-1987	Pass	669	0.7	7.8	1.5				
		Fail	147	1.8	20.4	2.4	111	1.3	15.3	1.7
All	1988-1991	Pass	1,883	0.3	4.3	0.9				
		Fail	252	1.2	14.0	1.7	190	0.6	9.0	1.0
P	1992-1995	Pass	657	0.1	1.9	0.4				
		Fail	80	0.4	5.8	1.0	53	0.2	4.2	0.6
P	1996-2000	Pass	971	0.0	1.2	0.2				
		Fail	14	0.2	6.9	0.7	15	0.2	5.7	0.5
T	1992-1995	Pass	1,214	0.2	3.0	0.7				
		Fail	265	0.5	8.7	1.4	290	0.3	4.6	1.0
T	1996-2000	Pass	2,277	0.1	1.0	0.3				
		Fail	37	0.7	6.1	1.4	47	0.1	2.2	0.8
P	2001 +	exempt		0.04	0.60	0.10				
T		exempt		0.08	0.60	0.10				

7.2 Counting Vehicles, Failures, Repairs, and Removals From Use

To evaluate the total mass emissions from the fleet as a whole and to calculate the emission reductions attributable the AirCare program, it was necessary to count the number of vehicles in use, how many passed or failed, how many were repaired, and how many were removed from use. Each count had to be stratified by vehicle type, age group, failure mode, and repair effectiveness.

The number of 1992 to 2000 model year vehicles in the fleet cannot be derived from a single year of inspection data. Because they are on a biennial inspection cycle, they can only be

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The number of 1992 to 2000 model year vehicles in the fleet cannot be derived from a single year of inspection data. Because they are on a biennial inspection cycle, they can only be

counted from two years of inspection data. For each model year, the total seen in the two-year period was counted. Discounting the very minor net effect of vehicle migration in and out of the area, these totals are taken to represent the number of such vehicles in use in 2001. Applying appropriate natural loss rates to each model year gave a corresponding number for 2002.

The number of 2001, 2002 and 2003 model year vehicles in use could not be derived from inspection data because these vehicles were exempt from inspection during the review period. Instead, their numbers have been derived from registration and licensing data, which shows a big increase in the number of new vehicles registered in the past two years.

Counting how many inspected vehicles passed, failed, etc., is not as simple as it might seem. A vehicle's cycle of inspection and licensing does not always fit nicely into a calendar year period. Vehicles that simply appear and pass every year are relatively simple to count, because they just have one inspection on one date. Conversely, the more trouble a vehicle has in complying with program requirements, the more likely it is to show an irregular pattern of inspections. For this evaluation, the first inspection for each vehicle in the calendar year has been used to establish the year's base mass emissions inventory. For vehicles that failed and then returned after repair, if the date of the re-inspection was within the same calendar year, then the benefit of the repair has been accredited to reducing the emissions inventory in that calendar year. The repair benefits for those vehicles that did not return for re-inspection until the next calendar year are included in assessing the base emissions inventory for that next year. Some vehicles fail inspection and are then removed from use rather than being repaired. Some of these can be identified as having been removed from use within the same calendar year, by applying the criterion that they did not return for successful re-inspection within three months of failing. There is a large emission benefit associated with removing a vehicle from use. When its removal from use follows shortly after a failed AirCare inspection, it is likely that the failure contributed to the decision to retire the vehicle, and therefore the inspection program could justifiably claim some part of the credit for the resulting emission reduction. The evaluation method has allowed a separate assessment of the benefit derived from removal from use in the same year. Other vehicles that failed late in the calendar year and were then removed from use were not separately identified. The benefits from their removal are included in assessing the base emissions inventory for the next year, because they simply did not show up for counting in that next year.

7.3 COMPLIANCE

There is very little scope for non-compliance with the AirCare program, because it is not possible to renew a vehicle's licence and insurance in the AirCare catchment area (ICBC Rating Territories D, E and H) without first complying with program requirements. There are couple ways that a vehicle can continue in use without complying. It is estimated that the total non-compliance rate is well below 1%.

7.4 ANNUAL MILEAGE AND VKMT

The light duty vehicle population was evaluated as explained in section 7.2, from the numbers of vehicles inspected and from registration and licensing data. Table 27 shows the number of vehicles and percentage of population by model year/technology groupings in 2001 and 2002. Annual mileage per vehicle has been calculated using the same method as previously reported (SAE Technical Paper # 961702). The calculation used a sample of 545,522 vehicles that were inspected in both 2001 and 2002. Multiplying the annual distance driven by the number of

vehicles in the fleet gives the total Vehicle Kilometres Travelled (VkmT). Table 27 also shows VkmT and also percentage of total VkmT attributable to each model year group.

Table 27. Number of Vehicles and VkmT in 2001 and 2002

		2001				2002			
Vehicle Type	Age Group	Number of Vehicles	Percentage of Population	VkmT 1000	Percentage of VkmT	Number of Vehicles	Percentage of Population	VkmT 1000	Percentage of VkmT
All	Pre-1972	7,711	1%	61,688	0%	6,959	1%	55,672	0%
All	1972-1981	45,198	4%	451,980	2%	36,760	3%	367,600	2%
All	1982-1987	149,491	13%	2,018,129	11%	127,541	11%	1,721,804	9%
All	1988-1991	254,781	22%	3,694,325	20%	236,605	20%	3,430,773	18%
All 1991 and Older		457,181	39%	6,226,121	33%	407,865	34%	5,575,848	29%
P	1992-1995	164,596	14%	2,633,536	14%	160,646	13%	2,570,331	13%
P	1996-2000	191,182	16%	3,154,503	17%	184,108	15%	3,037,786	16%
T	1992-1995	100,479	9%	1,909,101	10%	98,068	8%	1,863,283	10%
T	1996-2000	144,717	12%	2,821,982	15%	139,362	12%	2,717,568	14%
All 1992 - 2000		600,974	52%	10,519,122	56%	582,184	49%	10,188,968	52%
P	2001 +	62,401	5%	1,060,820	6%	118,409	10%	2,012,949	10%
T	2001 +	45,187	4%	903,741	5%	85,744	7%	1,714,885	9%
All 2001 and Newer		107,588	9%	1,964,561	11%	204,153	17%	3,727,834	19%
TOTAL		1,165,743	100%	18,709,803	100%	1,194,202	100%	19,492,650	100%

Pre-1992 vehicles accounted for 39% of the fleet in terms of population and 33% of the overall VkmT in 2001. These proportions dropped to 34% and 29%, respectively, in 2002.

1992-to-2000 model year vehicles accounted for 52% of the fleet and 56% of the VkmT in 2001, dropping to 49% and 52% in 2002.

The newest vehicles (2001 and 2002 model year) accounted for 9% of the fleet and 11% of the VkmT in 2001. With the addition of the 2002 model year vehicles, the contribution grew to 17% and 19% in 2002.

7.5 Results of Mass Emission Evaluations

7.5.1 Illustration of Repair Benefit and Removal-From-Use Benefit

Figure 54 illustrates in the form of a Venn diagram how the inspection program affects different groups of vehicles. There are four possible conditions:

1) Exempt from Testing

2) Pass First Time

3) Pass or Conditionally Pass after Failing Initial Test

4) Removed From Use

Note that the circles are not to scale.

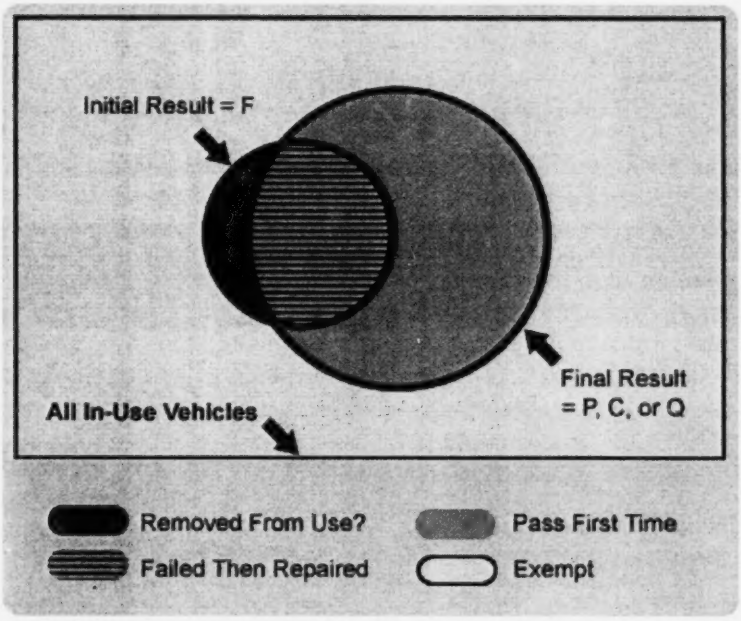

Figure 54. Repair and Remove-From-Use Benefit Illustration

- Exempt vehicles are not inspected and are therefore not directly affected by the program. They comprise vehicles less than two years old, and vehicles on the biennial test cycle that are in their off year.
- Most vehicles that are inspected pass their first inspection. Again, there can be no direct benefit from inspecting these vehicles, but the indirect benefits may result from vehicle owners taking better care of their vehicles as a result of wanting to avoid failing the emissions inspection.
- Vehicles that failed their first or multiple tests and are then repaired to comply are shown in the intersection area of the Venn diagram. Inspecting and failing these vehicles has the direct result of them being repaired, and is therefore the most obvious benefit of the program.
- Vehicles that fail, but do not subsequently comply, must have been removed from use in the program area (ignoring the possible non-compliance previously described). Removing a vehicle from use has a very large emissions benefit. If the only reason for the removal was an inspection failure, the benefit must be a direct benefit of the program. In practice, the inspection failure would more often be just a contributory factor in the decision to remove the vehicle from use. This type of inspection program benefit will be considered separately.

7.5.2 THE GVRD AND FVRD LIGHT-DUTY MOBILE SOURCE INVENTORIES

Total mass emissions calculated from IM240 mass emission factors, vehicle population and annual kilometres travelled cannot be directly equated to the light-duty mobile source inventory. The IM240 factors are derived from a specific, hot-start driving cycle and are only valid if all the vehicles drive exactly in that manner. Real-world driving includes a lot of off-cycle operation, and operating modes such as cold-start can dramatically increase emission rates above those

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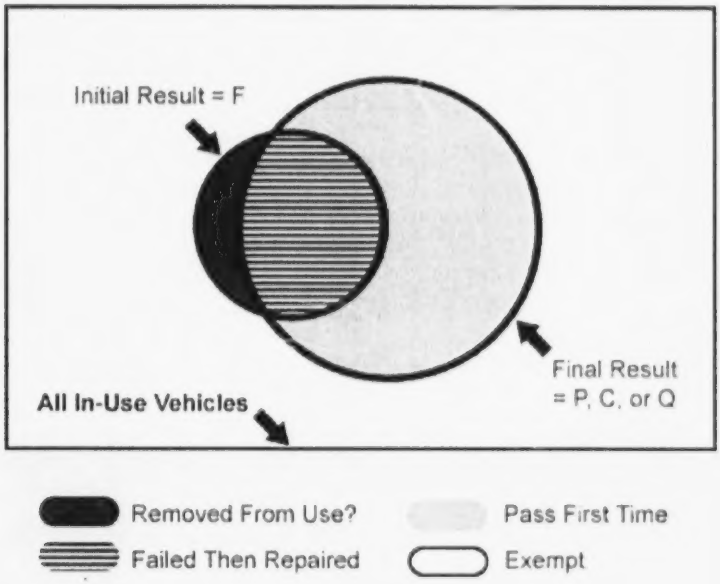

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7.5.2 The GVRD and FVRD Light-Duty Mobile Source Inventories

Total mass emissions calculated from IM240 mass emission factors, vehicle population and annual kilometres travelled cannot be directly equated to the light-duty mobile source inventory. The IM240 factors are derived from a specific, hot-start driving cycle and are only valid if all the vehicles drive exactly in that manner. Real-world driving includes a lot of off-cycle operation, and operating modes such as cold-start can dramatically increase emission rates above those

measured using the IM240 cycle. Inventory modelling takes all the off-cycle operation into account with the result that total emissions estimated from emission inventory models are considerably greater than those derived from IM240 emission factors. However, the percentage reductions in emissions according to the IM240 data can be applied to the real world model, because the effect should be proportional. For the purpose of this analysis the pre-repair total grams of each pollutant (number of passing vehicles multiplied by the passing vehicle emission factor plus the number of failing vehicles multiplied by the failing vehicle emission factor, each multiplied by the appropriate annual distance travelled) was compared to the post-repair total grams (passing vehicles plus the number of vehicles repaired to pass multiplied by the post-repair emission factor). The difference between the aggregated results was used to generate a percentage reduction. As the emission factors are expressed in grams/km, the multiplication of vehicle population by the emission factor and annual kilometres travelled produces a result in grams. Due to the magnitude of the results, units of Megagrams (Mg) are used throughout.

Table 28 takes the inventory from 2001 as the starting point for AirCare II, and then applies percentage reductions to calculate mass reductions, and the remaining inventory. The percentage reductions were calculated from the IM240 mass emission totals. Table 29 was also derived by applying percentage reductions to the 2001 base inventory.

Table 28. In-Use Light-Duty Vehicles Mass Emissions Inventory in 2001

Vehicle Type	Age Group	BASE			With REPAIRS			With RFUAF		
		Emission (Mg/Year)			Emission (Mg/Year)			Emission (Mg/Year)		
		HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
All	Pre-1972	910	6,203	197	679	4,754	201	417	2,980	158
All	1972-1981	3,117	22,612	1,753	2,488	19,826	1,553	1,760	15,333	1,240
All	1982-1987	6,558	66,181	5,073	5,952	60,972	4,732	5,067	52,049	4,175
All	1988-1991	4,975	63,747	5,064	4,082	57,609	4,716	3,682	52,850	4,416
All 1991 and Older		15,560	158,743	12,086	13,202	143,161	11,202	10,925	123,212	9,989
				Reduction in Year	2,358	15,582	884	4,635	35,531	2,097
				Reduction in Year from RFUAF				2,276	19,949	1,213
				Reduction from 2001 Base	2,358	15,582	884	4,635	35,531	2,097
P	1992-1995	1,085	19,078	1,668	1,023	18,243	1,627	1,001	17,907	1,603
P	1996-2000	522	13,056	870	517	12,926	864	517	12,907	863
T	1992-1995	1,455	24,372	2,346	1,387	22,951	2,273	1,354	22,446	2,230
T	1996-2000	650	9,753	1,270	619	9,585	1,262	613	9,547	1,259
All 1992 - 2000		3,712	66,260	6,153	3,546	63,705	6,026	3,484	62,807	5,955
				Reduction in Year	166	2,554	127	228	3,453	198
				Reduction in Year from RFUAF				62	898	71
				Reduction from 2001 Base	166	2,554	127	228	3,453	198
P	2001 +	143	1,992	152	143	1,992	152	143	1,992	152
T	2001 +	244	1,697	130	244	1,697	130	244	1,697	130
All 2001 and Newer		388	3,689	282	388	3,689	282	388	3,689	282
TOTAL		19,660	228,692	18,521	17,135	210,555	17,510	14,797	189,708	16,226
				Reduction in Year	2,524	18,136	1,012	4,862	38,984	2,295
				Reduction in Year from RFUAF				2,338	20,847	1,284
				Reduction from 2001 Base	2,524	18,136	1,012	4,862	38,984	2,295

7.5.2.1 Inventory Reductions Due to Repairs

As shown in Table 28, the reductions achieved from repairs in 2001 were 2,524 Mg/year for HC, 18,136 Mg/year for CO; and 1,012 Mg/year for NO_x. In 2002, Table 29, the reductions achieved from repairs were a little higher at 2,677 Mg/year for HC; 20,879 Mg/year for CO; and 1,187 Mg/year for NO_x. The mass reductions from repairs to 1991-and-older vehicles in 2002 were all lower than in 2001, even though their failure rates were much the same, because the population of these older vehicles was reduced. The mass reductions from repairs to vehicles from model years 1992 through 2000 in calendar year 2002 were all higher than in 2001. This increase can be explained by fewer vehicles being biennially exempt, an increased failure rate for those actually inspected, and few losses due to scrappage.

Table 29. In-Use Light-Duty Vehicles Mass Emissions Inventory in 2002

		BASE			with REPAIRS			with RFUAF		
Vehicle Type	Age Group	Emission (Mg)			Emission (gram)			Emission (gram)		
		HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
All	Pre-1972	803	5,460	176	599	4,182	180	379	2,686	145
All	1972-1981	2,503	18,642	1,416	2,003	16,024	1,257	1,461	12,622	1,029
All	1982-1987	5,645	56,759	4,323	5,127	52,445	4,048	4,363	44,807	3,587
All	1988-1991	4,869	60,636	4,751	3,889	54,458	4,389	3,460	49,587	4,089
All 1991 and Older		13,819	141,498	10,667	11,618	127,109	9,874	9,663	109,701	8,850
				Reduction in Year	2,201	14,389	792	4,156	31,797	1,816
				Reduction in Year from RFUAF				1,956	17,408	1,024
Reduction from 2001 Base		1,741	17,245	1,420	3,941	31,634	2,212	5,897	49,042	3,236
P	1992-1995	1,072	18,693	1,613	884	16,545	1,476	828	15,768	1,421
P	1996-2000	506	12,643	830	486	12,124	806	484	12,059	803
T	1992-1995	1,369	22,661	2,253	1,197	19,265	2,056	1,125	18,180	1,971
T	1996-2000	625	9,180	1,220	528	8,752	1,183	512	8,675	1,176
All 1992 - 2000		3,571	63,177	5,915	3,095	56,687	5,520	2,948	54,682	5,371
				Reduction in Year	476	6,490	395	623	8,495	544
				Reduction in Year from RFUAF				147	2,005	149
Reduction from 2001 Base		141	3,083	238	617	9,573	633	764	11,577	782
P	2001 +	272	3,780	289	272	3,780	289	272	3,780	289
T	2001 +	464	3,221	246	464	3,221	246	464	3,221	246
All 2001 and Newer		736	7,001	535	736	7,001	535	736	7,001	535
TOTAL		18,126	211,676	17,117	15,450	190,797	15,929	13,347	171,384	14,756
				Reduction in Year	2,677	20,879	1,187	4,779	40,292	2,360
				Reduction in Year from RFUAF				2,102	19,412	1,173
Reduction from 2001 Base		1,533	17,016	1,405	4,210	37,895	2,592	6,312	57,307	3,765

7.5.2.2 Inventory Reductions Due to Removal from Use After Failure

If a vehicle is removed from use after failing inspection, there is obviously a major emission benefit that results. Such removal from use is normally something associated with an old

measured using the IM240 cycle. Inventory modelling takes all the off-cycle operation into account with the result that total emissions estimated from emission inventory models are considerably greater than those derived from IM240 emission factors. However, the percentage reductions in emissions according to the IM240 data can be applied to the real world model, because the effect should be proportional. For the purpose of this analysis the pre-repair total grams of each pollutant (number of passing vehicles multiplied by the passing vehicle emission factor plus the number of failing vehicles multiplied by the failing vehicle emission factor, each multiplied by the appropriate annual distance travelled) was compared to the post-repair total grams (passing vehicles plus the number of vehicles repaired to pass multiplied by the post-repair emission factor). The difference between the aggregated results was used to generate a percentage reduction. As the emission factors are expressed in grams/km, the multiplication of vehicle population by the emission factor and annual kilometres travelled produces a result in grams. Due to the magnitude of the results, units of Megagrams (Mg) are used throughout.

Table 28 takes the inventory from 2001 as the starting point for AirCare II, and then applies percentage reductions to calculate mass reductions, and the remaining inventory. The percentage reductions were calculated from the IM240 mass emission totals. Table 29 was also derived by applying percentage reductions to the 2001 base inventory.

Table 28. In-Use Light-Duty Vehicles Mass Emissions Inventory in 2001

Vehicle Type	Age Group	BASE Emission (Mg/Year)			With REPAIRS Emission (Mg/Year)			With RFUAF Emission (Mg/Year)		
		HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
All	Pre-1972	910	6,203	197	679	4,754	201	417	2,980	158
All	1972-1981	3,117	22,612	1,753	2,488	19,826	1,553	1,760	15,333	1,240
All	1982-1987	6,558	66,181	5,073	5,952	60,972	4,732	5,067	52,049	4,175
All	1988-1991	4,975	63,747	5,064	4,082	57,609	4,716	3,682	52,850	4,416
All 1991 and Older		15,560	158,743	12,086	13,202	143,161	11,202	10,925	123,212	9,986
				Reduction in Year	2,358	15,582	884	4,635	35,531	2,097
				Reduction in Year from RFUAF				2,276	19,949	1,213
				Reduction from 2001 Base	2,358	15,582	884	4,635	35,531	2,097
P	1992-1995	1,085	19,078	1,668	1,023	18,243	1,627	1,001	17,907	1,603
P	1996-2000	522	13,056	870	517	12,926	864	517	12,907	863
T	1992-1995	1,455	24,372	2,346	1,387	22,951	2,273	1,354	22,446	2,230
T	1996-2000	650	9,753	1,270	619	9,585	1,262	613	9,547	1,259
All 1992 - 2000		3,712	66,260	6,153	3,546	63,705	6,026	3,484	62,807	5,955
				Reduction in Year	166	2,554	127	228	3,453	198
				Reduction in Year from RFUAF				62	898	71
				Reduction from 2001 Base	166	2,554	127	228	3,453	198
P	2001 +	143	1,992	152	143	1,992	152	143	1,992	152
T	2001 +	244	1,697	130	244	1,697	130	244	1,697	130
All 2001 and Newer		388	3,689	282	388	3,689	282	388	3,689	282
TOTAL		**19,660**	**228,692**	**18,521**	**17,135**	**210,555**	**17,510**	**14,797**	**189,708**	**16,226**
				Reduction in Year	**2,524**	**18,136**	**1,012**	**4,862**	**38,984**	**2,295**
				Reduction in Year from RFUAF				**2,338**	**20,847**	**1,284**
				Reduction from 2001 Base	**2,524**	**18,136**	**1,012**	**4,862**	**38,984**	**2,295**

7.5.2.1 Inventory Reductions Due to Repairs

As shown in Table 28, the reductions achieved from repairs in 2001 were 2,524 Mg/year for HC, 18,136 Mg/year for CO; and 1,012 Mg/year for NO_x. In 2002, Table 29, the reductions achieved from repairs were a little higher at 2,677 Mg/year for HC; 20,879 Mg/year for CO; and 1,187 Mg/year for NO_x. The mass reductions from repairs to 1991-and-older vehicles in 2002 were all lower than in 2001, even though their failure rates were much the same, because the population of these older vehicles was reduced. The mass reductions from repairs to vehicles from model years 1992 through 2000 in calendar year 2002 were all higher than in 2001. This increase can be explained by fewer vehicles being biennially exempt, an increased failure rate for those actually inspected, and few losses due to scrappage.

Table 29. In-Use Light-Duty Vehicles Mass Emissions Inventory in 2002

Vehicle Type	Age Group	BASE Emission (Mg)			with REPAIRS Emission (gram)			with RFUAF Emission (gram)		
		HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
All	Pre-1972	803	5,460	176	599	4,182	180	379	2,686	145
All	1972-1981	2,503	18,642	1,416	2,003	16,024	1,257	1,461	12,622	1,029
All	1982-1987	5,645	56,759	4,323	5,127	52,445	4,048	4,363	44,807	3,587
All	1988-1991	4,869	60,636	4,751	3,889	54,458	4,389	3,460	49,587	4,089
All 1991 and Older		13,819	141,498	10,667	11,618	127,109	9,874	9,663	109,701	8,850
				Reduction in Year	2,201	14,389	792	4,156	31,797	1,816
				Reduction in Year from RFUAF				1,956	17,408	1,024
Reduction from 2001 Base		1,741	17,245	1,420	3,941	31,634	2,212	5,897	49,042	3,236
P	1992-1995	1,072	18,693	1,613	884	16,545	1,476	828	15,768	1,421
P	1996-2000	506	12,643	830	486	12,124	806	484	12,059	803
T	1992-1995	1,369	22,661	2,253	1,197	19,265	2,056	1,125	18,180	1,971
T	1996-2000	625	9,180	1,220	528	8,752	1,183	512	8,675	1,176
All 1992 - 2000		3,571	63,177	5,915	3,095	56,687	5,520	2,948	54,682	5,371
				Reduction in Year	476	6,490	395	623	8,495	544
				Reduction in Year from RFUAF				147	2,005	149
Reduction from 2001 Base		141	3,083	238	617	9,573	633	764	11,577	782
P	2001 +	272	3,780	289	272	3,780	289	272	3,780	289
T	2001 +	464	3,221	246	464	3,221	246	464	3,221	246
All 2001 and Newer		736	7,001	535	736	7,001	535	736	7,001	535
TOTAL		**18,126**	**211,676**	**17,117**	**15,450**	**190,797**	**15,929**	**13,347**	**171,384**	**14,756**
				Reduction in Year	**2,677**	**20,879**	**1,187**	**4,779**	**40,292**	**2,360**
				Reduction in Year from RFUAF				**2,102**	**19,412**	**1,173**
Reduction from 2001 Base		**1,533**	**17,016**	**1,405**	**4,210**	**37,895**	**2,592**	**6,312**	**57,307**	**3,765**

7.5.2.2 Inventory Reductions Due to Removal from Use After Failure

If a vehicle is removed from use after failing inspection, there is obviously a major emission benefit that results. Such removal from use is normally something associated with an old

vehicle that is approaching the end of its useful life anyway, and these vehicles have much higher emissions than newer vehicles, so the benefits of their removal can be very high. Usually there would be many factors contributing to the decision to stop using a vehicle, and failing an emissions inspection may just be the last nail in the coffin. To decide how much of the removal benefit can reasonably be attributed to the inspection program we would need to know which vehicles would have continued in use had they not failed inspection. Of course, we cannot determine this from the data available, but we can estimate the total benefit derived from removal of vehicles after failing an inspection.

To consider a vehicle as having been removed from use after having failed inspection, we applied the condition that it did not return for a pass or waiver within a period lasting at least three months. In practice, we took all the vehicles that failed from January to September that did not return to pass or waiver within the calendar year. Those that failed late in September did not successfully return within three months, and those that failed in January did not successfully return within almost twelve months. Almost all of these vehicles must have been removed from use in the program area, and they represent approximately 75% of the number that would be removed in one year.

Table 28 and Table 29 include estimates of the inventories that result after including the reductions from removing vehicles after they failed. The emissions reduction benefit derived from removing these vehicles from use is equal to the sum of their emission rates multiplied by their annual mileage. In 2001, removal from use after failure lowered the inventory emission rates by 2,338 Mg/year for HC; 20,847 Mg/year for CO; and 1,284 Mg/year for NO_x. In 2002 the reductions were 2,102 Mg/year for HC; 19,412 Mg/year for CO; and 1,173 Mg/year for NO_x. Almost all of these reductions came from the older vehicles.

7.5.2.3 Overall Change in Base Inventory from 2001 to 2002

The 2002 base inventory (the inventory at the beginning of the calendar year) was lower than in 2001. Although there was obviously an increase for 2001 and newer vehicles, the repairs to, and removal of, older vehicles more than outweighed the small increase caused by the addition of these low-emitting new vehicles. The 2002 base shows reductions of 1,533 Mg/year HC; 17,016 Mg/year CO; and 1,405 Mg/year NO_x from the 2001 base.

Comparing the 2002 base with the after-repairs inventory for 2001, it shows an overall increase for HC, a very small increase for CO, and a slight decrease for NO_x. These changes are partly because of the addition of new vehicles, partly because of deterioration of repairs, and partly because of some vehicles being removed from use, with a smaller number maybe coming back into use after temporary removal.

The 2002 base inventory is the emission rates that would have prevailed throughout 2002 if there were no inspection program in 2002. It is important to clearly distinguish it from the inventory that would have existed had there never been an inspection program. This last scenario didn't happen, it is imaginary, and there has been an inspection program ever since 1992. To model what would have happened if AirCare had never been instituted would be quite speculative.

7.5.2.4 Mass of Emissions Prevented

The inventory numbers shown in Table 28 and Table 29, and just discussed, are Emission Rates, and are in units of Mg/year. If all the emission repair benefits are evenly spread throughout the year, the total mass (Mg) prevented from being emitted in the year is half of the difference between the base rate and the with-repairs rate. Therefore mass emissions prevented by repairs in 2001 were 1,262 Mg HC; 9,068 Mg CO; and 506 Mg NO_x. In 2002, the mass emissions prevented by repairs were 1,338 Mg HC; 10,440 Mg CO; and 594 Mg NO_x.

Similarly, if all-the-removal-from-use-after-failure benefits are spread evenly throughout the year, the total mass (Mg) prevented from being emitted in the year is half of the difference between the with-repairs rate, and the with-repairs-and-RFUAF rate. Thus the mass emissions prevented by RFUAF in 2001 were 1,318 Mg HC; 11,756 Mg CO; and 724 Mg NO_x. In 2002 the mass emissions prevented by RFUAF were 1,186 Mg HC; 10,947 Mg CO; and 662 Mg NO_x. We are not able to positively determine how much of these benefits can be credited to the inspection program.

7.5.3 Percentage Reductions Due to Repairs

The percentage reductions achieved during 2001 and 2002 are shown Table 30 and Table 31. Except for the rightmost three columns, in Table 31 all reductions are referred from the base inventory for 2001.

Table 30. Percentage Emission Reductions Due to Repairs in 2001

Vehicle Type	Age Group	BASE			With REPAIR Reduction from 2001 Base		
		HC	CO	NOx	HC	CO	NOx
All	Pre-1972	0%	0%	0%	25%	23%	-2%
All	1972-1981	0%	0%	0%	20%	12%	11%
All	1982-1987	0%	0%	0%	9%	8%	7%
All	1988-1991	0%	0%	0%	18%	10%	7%
All 1991 and Older		0%	0%	0%	15%	10%	7%
P	1992-1995	0%	0%	0%	6%	4%	2%
P	1996-2000	0%	0%	0%	1%	1%	1%
T	1992-1995	0%	0%	0%	5%	6%	3%
T	1996-2000	0%	0%	0%	5%	2%	1%
All 1992 - 2000		0%	0%	0%	4%	4%	2%
P	2001 +	0%	0%	0%	0%	0%	0%
T	2001 +	0%	0%	0%	0%	0%	0%
All 2001 and Newer		0%	0%	0%	0%	0%	0%
TOTAL		0%	0%	0%	13%	8%	5%

The total percentage reductions achieved after repairs were 13% HC; 8% CO; and 5% NO_x in 2001 as shown in Table 30. These percentage reductions all increased for 2002 repairs, to 15% HC; 10% CO; and 7% NO_x as shown in Table 31.

7.5.2.4 Mass of Emissions Prevented

The inventory numbers shown in Table 28 and Table 29, and just discussed, are Emission Rates, and are in units of Mg/year. If all the emission repair benefits are evenly spread throughout the year, the total mass (Mg) prevented from being emitted in the year is half of the difference between the base rate and the with-repairs rate. Therefore mass emissions prevented by repairs in 2001 were 1,262 Mg HC; 9,068 Mg CO; and 506 Mg NO_x. In 2002, the mass emissions prevented by repairs were 1,338 Mg HC; 10,440 Mg CO; and 594 Mg NO_x.

Similarly, if all-the-removal-from-use-after-failure benefits are spread evenly throughout the year, the total mass (Mg) prevented from being emitted in the year is half of the difference between the with-repairs rate, and the with-repairs-and-RFUAF rate. Thus the mass emissions prevented by RFUAF in 2001 were 1,318 Mg HC; 11,756 Mg CO; and 724 Mg NO_x. In 2002 the mass emissions prevented by RFUAF were 1,186 Mg HC; 10,947 Mg CO; and 662 Mg NO_x. We are not able to positively determine how much of these benefits can be credited to the inspection program.

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Table 30. Percentage Emission Reductions Due to Repairs in 2001

Vehicle Type	Age Group	BASE			With REPAIR Reduction from 2001 Base		
		HC	CO	NOx	HC	CO	NOx
All	Pre-1972	0%	0%	0%	25%	23%	-2%
All	1972-1981	0%	0%	0%	20%	12%	11%
All	1982-1987	0%	0%	0%	9%	8%	7%
All	1988-1991	0%	0%	0%	18%	10%	7%
All 1991 and Older		0%	0%	0%	15%	10%	7%
P	1992-1995	0%	0%	0%	6%	4%	2%
P	1996-2000	0%	0%	0%	1%	1%	1%
T	1992-1995	0%	0%	0%	5%	6%	3%
T	1996-2000	0%	0%	0%	5%	2%	1%
All 1992 - 2000		0%	0%	0%	4%	4%	2%
P	2001 +	0%	0%	0%	0%	0%	0%
T	2001 +	0%	0%	0%	0%	0%	0%
All 2001 and Newer		0%	0%	0%	0%	0%	0%
TOTAL		0%	0%	0%	13%	8%	5%

The total percentage reductions achieved after repairs were 13% HC; 8% CO; and 5% NO_x in 2001 as shown in Table 30. These percentage reductions all increased for 2002 repairs, to 15% HC; 10% CO; and 7% NO_x as shown in Table 31.

The 2002 base inventory was lower than the 2001 base inventory by 8% HC; 7% CO; and 8% NO_x. After considering repairs in 2002 the total inventory reductions achieved from the beginning of 2001 through the end of 2002 were 21% HC; 17% CO; and 14% NO_x.

The biggest percentage reductions due to repair were for the older vehicles. The percentage reductions for newer vehicles were much bigger in 2002 than in 2001, because more were inspected, and higher failure rates resulting in more repairs.

Hydrocarbon emission reductions were almost always greatest, with NO_x emissions showing the least reductions. In the oldest age group (pre-1972), repairs consistently increased NO_x emissions.

Table 31. Percentage Emission Reductions Due to Repairs in 2002

Vehicle Type	Age Group	Reduction from 2001 Base			With REPAIRS Reduction from 2001 Base			With REPAIRS Reduction from 2002 Base		
		HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
All	Pre-1972	12%	12%	10%	34%	33%	9%	25%	23%	-2%
All	1972-1981	20%	18%	19%	36%	29%	28%	20%	14%	11%
All	1982-1987	14%	14%	15%	22%	21%	20%	9%	8%	6%
All	1988-1991	2%	5%	6%	22%	15%	13%	20%	10%	8%
All 1991 and Older		11%	11%	12%	25%	20%	18%	16%	10%	7%
P	1992-1995	1%	2%	3%	19%	13%	11%	17%	11%	9%
P	1996-2000	3%	3%	5%	7%	7%	7%	4%	4%	3%
T	1992-1995	6%	7%	4%	18%	21%	12%	13%	15%	9%
T	1996-2000	4%	6%	4%	19%	10%	7%	16%	5%	3%
All 1992 - 2000		4%	5%	4%	17%	14%	10%	13%	10%	7%
P	2001 +	-90%	-90%	-90%	-90%	-90%	-90%	0%	0%	0%
T	2001 +	-90%	-90%	-90%	-90%	-90%	-90%	0%	0%	0%
All 2001 and Newer		-90%	-90%	-90%	-90%	-90%	-90%	0%	0%	0%
TOTAL		8%	7%	8%	21%	17%	14%	15%	10%	7%

7.5.4 INVENTORY CONTRIBUTIONS

Stratification of the mass emission evaluation allows the contributions of the different strata to be compared. Table 32 and Table 33 shows the percentage contributions by age group and vehicle type for each calendar year and condition in 2001 and 2002.

Each column adds up to 100%. The base numbers for 2001 show that 1991-and-older vehicles accounted for 79% of HC; 69% of CO; and 65% of NO_x. So these older vehicles produced between two thirds to three quarters of the base inventory. Their percentage contributions after repair and after removing some failed vehicles from use, are lower, because repairs can often produce a major improvement, and removal from use obviously delivers 100% improvement. The contributions of pre-1992 vehicles to the base 2002 inventory declined only slightly to 76% of HC; 67% of CO; and 62% of NO_x, because, although their numbers are decreasing, they are replaced with much cleaner new vehicles, meaning that the total inventory is less.

1992 through 2000 model year vehicles contributed 19% of HC; 29% of CO; and 33% of NO_x to the 2001 base inventory. Their percentage contributions increased after repair and removal are considered, not because they actually got worse, but because repairs to and removal of older vehicles lowered the total inventory. Their contributions to the 2002 base inventory increased a little from the 2001 base, because of the removal of many older vehicles from use.

Table 32. Percentage Contributions in 2001

Vehicle Type	Age Group	BASE			with REPAIRS		
		HC	CO	NOx	HC	CO	NOx
All	Pre-1972	5%	3%	1%	4%	2%	1%
All	1972-1981	16%	10%	9%	15%	9%	9%
All	1982-1987	33%	29%	27%	35%	29%	27%
All	1988-1991	25%	28%	27%	24%	27%	27%
All 1991 and Older		79%	69%	65%	77%	68%	64%
P	1992-1995	6%	8%	9%	6%	9%	9%
P	1996-2000	3%	6%	5%	3%	6%	5%
T	1992-1995	7%	11%	13%	8%	11%	13%
T	1996-2000	3%	4%	7%	4%	5%	7%
All 1992 - 2000		19%	29%	33%	21%	30%	34%
P	2001 +	1%	1%	1%	1%	1%	1%
T	2001 +	1%	1%	1%	1%	1%	1%
All 2001 and Newer		2%	2%	2%	2%	2%	2%
TOTAL		100%	100%	100%	100%	100%	100%

Table 33. Percentage Contributions in 2002

Vehicle Type	Age Group	BASE			with REPAIRS		
		HC	CO	NOx	HC	CO	NOx
All	Pre-1972	4%	3%	1%	4%	2%	1%
All	1972-1981	14%	9%	8%	13%	8%	8%
All	1982-1987	31%	27%	25%	33%	27%	25%
All	1988-1991	27%	29%	28%	25%	29%	28%
All 1991 and Older		76%	67%	62%	75%	67%	62%
P	1992-1995	6%	9%	9%	6%	9%	9%
P	1996-2000	3%	6%	5%	3%	6%	5%
T	1992-1995	8%	11%	13%	8%	10%	13%
T	1996-2000	3%	4%	7%	3%	5%	7%
All 1992 - 2000		20%	30%	35%	20%	30%	35%
P	2001 +	2%	2%	2%	2%	2%	2%
T	2001 +	3%	2%	1%	3%	2%	2%
All 2001 and Newer		4%	3%	3%	5%	4%	3%
TOTAL		100%	100%	100%	100%	100%	100%

The 2002 base inventory was lower than the 2001 base inventory by 8% HC; 7% CO; and 8% NO_x. After considering repairs in 2002 the total inventory reductions achieved from the beginning of 2001 through the end of 2002 were 21% HC; 17% CO; and 14% NO_x.

The biggest percentage reductions due to repair were for the older vehicles. The percentage reductions for newer vehicles were much bigger in 2002 than in 2001, because more were inspected, and higher failure rates resulting in more repairs.

Hydrocarbon emission reductions were almost always greatest, with NO_x emissions showing the least reductions. In the oldest age group (pre-1972), repairs consistently increased NO_x emissions.

Table 31. Percentage Emission Reductions Due to Repairs in 2002

Vehicle Type	Age Group	Reduction from 2001 Base			With REPAIRS Reduction from 2001 Base			With REPAIRS Reduction from 2002 Base		
		HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
All	Pre-1972	12%	12%	10%	34%	33%	9%	25%	23%	-2%
All	1972-1981	20%	18%	19%	36%	29%	28%	20%	14%	11%
All	1982-1987	14%	14%	15%	22%	21%	20%	9%	8%	6%
All	1988-1991	2%	5%	6%	22%	15%	13%	20%	10%	8%
All 1991 and Older		11%	11%	12%	25%	20%	18%	16%	10%	7%
P	1992-1995	1%	2%	3%	19%	13%	11%	17%	11%	9%
P	1996-2000	3%	3%	5%	7%	7%	7%	4%	4%	3%
T	1992-1995	6%	7%	4%	18%	21%	12%	13%	15%	9%
T	1996-2000	4%	6%	4%	19%	10%	7%	16%	5%	3%
All 1992 - 2000		4%	5%	4%	17%	14%	10%	13%	10%	7%
P	2001 +	-90%	-90%	-90%	-90%	-90%	-90%	0%	0%	0%
T	2001 +	-90%	-90%	-90%	-90%	-90%	-90%	0%	0%	0%
All 2001 and Newer		-90%	-90%	-90%	-90%	-90%	-90%	0%	0%	0%
TOTAL		8%	7%	8%	21%	17%	14%	15%	10%	7%

7.5.4 INVENTORY CONTRIBUTIONS

Stratification of the mass emission evaluation allows the contributions of the different strata to be compared. Table 32 and Table 33 shows the percentage contributions by age group and vehicle type for each calendar year and condition in 2001 and 2002.

Each column adds up to 100%. The base numbers for 2001 show that 1991-and-older vehicles accounted for 79% of HC; 69% of CO; and 65% of NO_x. So these older vehicles produced between two thirds to three quarters of the base inventory. Their percentage contributions after repair and after removing some failed vehicles from use, are lower, because repairs can often produce a major improvement, and removal from use obviously delivers 100% improvement. The contributions of pre-1992 vehicles to the base 2002 inventory declined only slightly to 76% of HC; 67% of CO; and 62% of NO_x, because, although their numbers are decreasing, they are replaced with much cleaner new vehicles, meaning that the total inventory is less.

1992 through 2000 model year vehicles contributed 19% of HC; 29% of CO; and 33% of NO_x to the 2001 base inventory. Their percentage contributions increased after repair and removal are considered, not because they actually got worse, but because repairs to and removal of older vehicles lowered the total inventory. Their contributions to the 2002 base inventory increased a little from the 2001 base, because of the removal of many older vehicles from use.

Table 32. Percentage Contributions in 2001

Vehicle Type	Age Group	BASE			with REPAIRS		
		HC	CO	NOx	HC	CO	NOx
All	Pre-1972	5%	3%	1%	4%	2%	1%
All	1972-1981	16%	10%	9%	15%	9%	9%
All	1982-1987	33%	29%	27%	35%	29%	27%
All	1988-1991	25%	28%	27%	24%	27%	27%
All 1991 and Older		79%	69%	65%	77%	68%	64%
P	1992-1995	6%	8%	9%	6%	9%	9%
P	1996-2000	3%	6%	5%	3%	6%	5%
T	1992-1995	7%	11%	13%	8%	11%	13%
T	1996-2000	3%	4%	7%	4%	5%	7%
All 1992 - 2000		19%	29%	33%	21%	30%	34%
P	2001 +	1%	1%	1%	1%	1%	1%
T	2001 +	1%	1%	1%	1%	1%	1%
All 2001 and Newer		2%	2%	2%	2%	2%	2%
TOTAL		100%	100%	100%	100%	100%	100%

Table 33. Percentage Contributions in 2002

Vehicle Type	Age Group	BASE			with REPAIRS		
		HC	CO	NOx	HC	CO	NOx
All	Pre-1972	4%	3%	1%	4%	2%	1%
All	1972-1981	14%	9%	8%	13%	8%	8%
All	1982-1987	31%	27%	25%	33%	27%	25%
All	1988-1991	27%	29%	28%	25%	29%	28%
All 1991 and Older		76%	67%	62%	75%	67%	62%
P	1992-1995	6%	9%	9%	6%	9%	9%
P	1996-2000	3%	6%	5%	3%	6%	5%
T	1992-1995	8%	11%	13%	8%	10%	13%
T	1996-2000	3%	4%	7%	3%	5%	7%
All 1992 - 2000		20%	30%	35%	20%	30%	35%
P	2001 +	2%	2%	2%	2%	2%	2%
T	2001 +	3%	2%	1%	3%	2%	2%
All 2001 and Newer		4%	3%	3%	5%	4%	3%
TOTAL		100%	100%	100%	100%	100%	100%

New (2001 and newer model years) vehicles have very little contribution to the inventory, even though new vehicle registrations have increased quite dramatically. Their contributions in 2002 are about double those in 2001 because of the additional model year.

The overall picture that emerges from these inventory contributions can only be appreciated by simultaneously considering the vehicle numbers, percentage of population, and percentage of VkmT as shown in Table 27.

The two pie charts in Figure 55 and Figure 56 show the Pareto relationship between emissions contribution and VkmT contribution. Emissions are shown as a whole for simplicity. Judged by their VkmT contributions of 19% and 29%, the 2001+ vehicles and the 1996-2000 vehicles make much less than their fair share of emissions, at 4% and 10% respectively. The 1992-1995 vehicles are also better than fleet average, with 23% of VkmT but only 18% of emissions. But the relationship gets increasingly worse for older vehicles. 1988-1991 model years contribute only 18% of VkmT but 27% of emissions. 1982-1987 model years contribute only 9% of VkmT but more than three times their fair share of emissions at 29%. 1972-1981 model years contribute just 2% of VkmT with five times their share of emissions at 10%. And pre-1972 vehicles contribute just 0.3% of VkmT but more than six times their share at 1.9% of emissions.

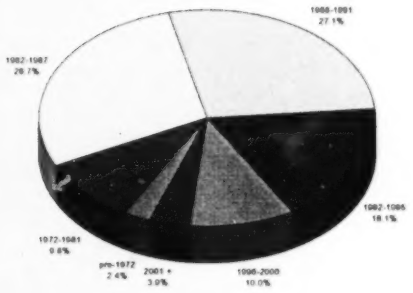

Figure 55. Emission Contribution

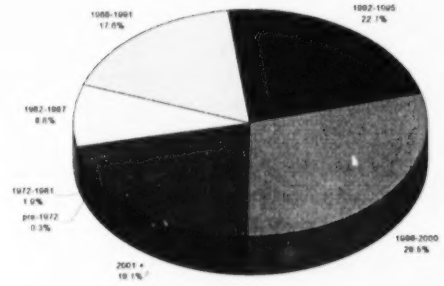

Figure 56. VkmT Contribution

7.6 DIESEL EMISSION REDUCTIONS

There is no reliable way of using the limited data available to confidently estimate the diesel emission reductions that have been achieved as a result of repairs. But because this is an important issue, it is equally important that some rough estimate be attempted.

The present diesel inspection procedure has been much more successful in identifying excessively smoking diesel vehicles than was the procedure used during AirCare I. The number of diesel vehicles in the fleet during 2001 and 2002 was 21,066. Those of model years 1992 and newer (10,955 vehicles) required a biennial inspection, and older vehicles (10,111 vehicles) required an annual inspection. There were 1,544 older vehicles failed, and 178 newer vehicles. Of these, the numbers repaired to pass were 1,181 and 159 respectively. The remaining failed vehicles may have already dropped out of use, or still be awaiting repair and re-inspection.

Based on the opacity reductions, described in a later section of this report, and on original certification standards, we have estimated the mass emission reductions of particulate matter, PM, as about 0.2 g/km for each vehicle repaired.

Applying this emission reduction factor to all the 1,340 vehicles that were successfully repaired, and taking their average annual mileage as 20,000 km, results in a total PM emissions inventory reduction of about 5.4 tonnes per year. It must be emphasized that this is only an estimate.

7.7 ASM Space and Idle Space

7.7.1 Dimensional ASM Space and Idle Space

Mean emission readings for ASM/Idle inspections on 1991-and-older vehicles are shown in Table 34 to Table 39. These averages have been calculated on the basis of individual vehicles, and those vehicles that have had multiple inspections were not counted multiple times. Only the passing inspections show any discernable difference between 2001 and 2002, with the average 2002 reading being slightly lower than 2001. For all other conditions, such as failing, and before and after repair, there was so little difference between 2001 and 2002 as to be insignificant, thus the table only shows the means for 2002 inspections.

For passing inspections in either calendar year, the direct relationship between vehicle model year and mean readings is very clear (Table 34). The newest group (1988-1991) are all Tier 0 vehicles and their mean readings are all less than half those for the next oldest group (1982-1987), which, in Canada, was a mixture of Tier 0 and Canadian-recalibrated vehicles. The next age group (1972-1981) is only slightly higher than the 1982-1987 group. The oldest group (pre-1972) shows a very big increase for HC and for CO, but only a small one for NO_x.

Table 34. ASM and Idle Space Mean Emissions Readings in 2001 and 2002

		Age Group	Idle HC (ppm)	Idle CO (%)	ASM HC (ppm)	ASM CO (%)	ASM NOx (ppm)
2001	PASS	Pre-1972	296	2.23	119	0.95	1,239
		1972-1981	144	1.58	72	0.44	1,146
		1982-1987	102	0.79	68	0.37	1,027
		1988-1991	41	0.18	29	0.14	386
2002	PASS	Pre-1972	281	2.11	118	1.04	1,232
		1972-1981	139	1.50	71	0.44	1,149
		1982-1987	98	0.72	69	0.37	1,029
		1988-1991	39	0.15	31	0.15	404
	FAIL	Pre-1972	874	5.05	265	2.79	960
		1972-1981	550	3.14	189	1.42	1,286
		1982-1987	376	2.22	157	1.45	1,572
		1988-1991	210	1.25	110	1.03	963

As already mentioned, the mean readings for inspections that passed show a consistent decrease from 2001 to 2002. This could be claimed as direct evidence of improved maintenance and effective repairs. But although these can contribute, there are other effects,

Based on the opacity reductions, described in a later section of this report, and on original certification standards, we have estimated the mass emission reductions of particulate matter, PM, as about 0.2 g/km for each vehicle repaired.

Applying this emission reduction factor to all the 1,340 vehicles that were successfully repaired, and taking their average annual mileage as 20,000 km, results in a total PM emissions inventory reduction of about 5.4 tonnes per year. It must be emphasized that this is only an estimate.

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For passing inspections in either calendar year, the direct relationship between vehicle model year and mean readings is very clear (Table 34). The newest group (1988-1991) are all Tier 0 vehicles and their mean readings are all less than half those for the next oldest group (1982-1987), which, in Canada, was a mixture of Tier 0 and Canadian-recalibrated vehicles. The next age group (1972-1981) is only slightly higher than the 1982-1987 group. The oldest group (pre-1972) shows a very big increase for HC and for CO, but only a small one for NO_x.

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		1988-1991	39	0.15	31	0.15	404
	FAIL	Pre-1972	874	5.05	265	2.79	960
		1972-1981	550	3.14	189	1.42	1,286
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As already mentioned, the mean readings for inspections that passed show a consistent decrease from 2001 to 2002. This could be claimed as direct evidence of improved maintenance and effective repairs. But although these can contribute, there are other effects,

the most important of which is vehicle retirement. The 2002 in-use fleet contains only 450,000 1991-and-older model year vehicles, compared to 500,000 in 2001. If the 50,000 vehicles that dropped out of the fleet had higher-than-average emissions, removing them from use would lower the mean readings, even if all the remaining vehicles stayed exactly the same. Indeed, it seems reasonable to assume that the most poorly maintained vehicles would be most likely to be removed. But conversely, our experience in studying vehicles retired as part of the Scrap-it Program has indicated that there appears to be very little correlation between a vehicle's emissions performance, and its overall condition. More analysis is needed of what vehicles are removed from use, and how they compare to those that remain in use.

The mean HC and CO readings from failed inspections were all more than twice the means from passed inspections (Table 34). For NO_x, back to 1972 model year, the mean readings were all higher for failed inspections than for passed. But for pre-1972 vehicles the mean NO_x reading was higher for passed inspections, which is consistent with the established emissions pattern from these old vehicles and their lack of NO_x emissions controls.

For the data pertaining to failing vehicles, there is the usual effect of higher average readings for older vehicles. However, the proportional difference with age for these failed inspection means are not as extreme as for the passed inspection means, suggesting that defective vehicles of any age have similarly high emissions.

The before- and after-repair means for vehicles that were repaired have been separated into three groups, dependent on their final result of P, C or Q. The before-repair condition is shown in Table 35, and the after-repair condition in Table 36. Some vehicles that failed did not subsequently achieve a pass or conditional pass; they contribute to the failure mean readings shown in Table 34, but are not shown separately.

Table 35. ASM and Idle Space Mean Emissions Readings Before Repair

	Age Group	Idle HC (ppm)	Idle CO (%)	ASM HC (ppm)	ASM CO (%)	ASM NOx (ppm)
BEFORE REPAIR TO PASS	Pre-1972	773	5.07	230	2.52	1,029
	1972-1981	546	3.38	180	1.35	1,381
	1982-1987	388	2.40	159	1.48	1,737
	1988-1991	218	1.33	116	1.13	1,050
BEFORE REPAIR TO C WAIVER	Pre-1972	1,066	4.95	404	4.01	734
	1972-1981	768	3.32	250	2.13	1,130
	1982-1987	500	2.38	222	2.42	1,318
	1988-1991	350	1.58	161	1.33	1,115
BEFORE REPAIR TO Q WAIVER	Pre-1972	779	4.84	305	3.23	920
	1972-1981	558	3.51	175	1.89	1,215
	1982-1987	400	2.47	185	1.99	1,733
	1988-1991	228	1.41	128	1.26	1,105

Table 36. ASM and Idle Space Mean Emissions Readings After Repair

	Age Group	Idle HC (ppm)	Idle CO (%)	ASM HC (ppm)	ASM CO (%)	ASM NOx (ppm)
REPAIRED TO PASS	Pre-1972	304	2.17	111	1.13	992
	1972-1981	142	1.22	70	0.46	978
	1982-1987	105	0.63	69	0.39	1,040
	1988-1991	43	0.10	37	0.14	446
REPAIRED TO C WAIVER	Pre-1972	896	3.99	321	3.84	629
	1972-1981	596	2.25	205	1.96	1,006
	1982-1987	396	1.54	183	2.05	1,305
	1988-1991	278	0.94	134	0.98	1,020
REPAIRED TO Q WAIVER	Pre-1972	619	3.05	216	3.16	904
	1972-1981	318	1.82	185	1.76	1,032
	1982-1987	258	1.30	154	1.59	1,439
	1988-1991	133	0.58	100	0.79	920

We have previously seen a relationship between the severity of failure and the decision to have repairs performed at a certified repair shop. The idea being that some failures (often extreme failures, caused by a known problem) immediately suggest that an expensive repair would be required, and a cost waiver is the obvious way to avoid such expense for at least one more year. For all age groups, the mean HC emissions (especially at idle) for vehicles that subsequently receive a cost waiver are noticeably higher than for vehicles that will be repaired to pass or to Q waiver. This would be consistent with a need for major engine work. Idle CO does not show a similar pattern, maybe because idle CO problems are usually perceived as simple repairs. But the effect could account for ASM CO "before repair to C waiver" readings being higher than "repairs to pass" vehicles or "repair to Q waiver" vehicles. ASM CO is a more difficult to problem to diagnose, and can be expensive to repair, often requiring complete carburetor rebuild or replacement, which would go beyond the repair cost limit. There does not appear to be any such obvious behaviour associated with NO_x mean readings.

After repair, the mean readings for passing vehicles are almost all lower than for vehicles that achieved only a Conditional Pass. Passing vehicles all achieved a pass, whereas vehicles receiving a waiver had at least one reading over the cut-point, so this is natural. The one exception is for NO_x in the pre-1972 age group, which often show increased NO_x as a side effect of repairs for CO problems.

With a similar exception for NO_x, the after-repair readings for C waiver vehicles were higher than those that received a Q waiver. The general explanation is that to receive a Q waiver, the repair technician must believe that all necessary repairs have been completed, and that the vehicle should pass, but for a C waiver it is fully accepted that necessary repairs have been left undone and a failure is expected. Thus Q waivers deliver more emissions benefit than C waivers, but not as much as a real pass. However, a Q waiver indicates an inadequate diagnosis or faulty repair, meaning that the full potential was not realized.

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The before- and after-repair means for vehicles that were repaired have been separated into three groups, dependent on their final result of P, C or Q. The before-repair condition is shown in Table 35, and the after-repair condition in Table 36. Some vehicles that failed did not subsequently achieve a pass or conditional pass; they contribute to the failure mean readings shown in Table 34, but are not shown separately.

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Comparing repaired-to-pass readings with readings from vehicles that passed-first-time shows very little difference. So the average passing readings do not seem to be affected by the previous pass/fail history of the vehicles involved.

7.7.2 NON-DIMENSIONAL ASM SPACE AND IDLE SPACE

Mean non-dimensional (normalized) emission values for ASM and idle inspections on 1991 and older vehicles are shown in Table 37 to Table 39. The non-dimensional figure has been determined by taking the quotient of the reading and its associated cut-point. Thus a value greater than unity is over the cut-point (failure), and less than unity is below the cut-point (pass). The average non-dimensional reading indicates how well the group is passing, or how badly it is failing.

Table 37. ASM and Idle Space Mean Non-Dimensional Emissions Readings

		Age Group	Idle HC (non-dim)	Idle CO (non-dim)	ASM HC (non-dim)	ASM CO (non-dim)	ASM NOx (non dim)
2001	PASS	Pre-1972	0.32	0.48	0.42	0.34	0.41
		1972-1981	0.29	0.34	0.30	0.24	0.43
		1982-1987	0.28	0.19	0.29	0.20	0.40
		1988-1991	0.31	0.18	0.26	0.17	0.31
2002	PASS	Pre-1972	0.30	0.46	0.39	0.33	0.38
		1972-1981	0.28	0.32	0.29	0.23	0.43
		1982-1987	0.27	0.18	0.30	0.20	0.41
		1988-1991	0.29	0.14	0.28	0.18	0.32
	FAIL	Pre-1972	0.93	1.10	0.91	0.99	0.31
		1972-1981	1.22	0.70	0.82	0.80	0.53
		1982-1987	1.03	0.55	0.69	0.83	0.64
		1988-1991	1.54	1.22	0.98	1.26	0.76

Table 38. ASM and Idle Space Mean Non-Dimensional Emissions Readings Before Repair

	Age Group	Idle HC (non-dim)	Idle CO (non-dim)	ASM HC (non-dim)	ASM CO (non-dim)	ASM NOx (non dim)
BEFORE REPAIR TO PASS	Pre-1972	0.82	1.10	0.80	0.90	0.33
	1972-1981	1.20	0.75	0.77	0.76	0.57
	1982-1987	1.07	0.59	0.70	0.85	0.71
	1988-1991	1.60	1.31	1.04	1.40	0.84
BEFORE REPAIR TO C WAIVER	Pre-1972	1.15	1.08	1.41	1.49	0.25
	1972-1981	1.79	0.75	1.12	1.27	0.49
	1982-1987	1.38	0.59	0.98	1.39	0.55
	1988-1991	2.58	1.52	1.44	1.62	0.89
BEFORE REPAIR TO Q WAIVER	Pre-1972	0.83	1.05	1.01	1.18	0.31
	1972-1981	1.25	0.80	0.80	1.15	0.54
	1982-1987	1.10	0.61	0.83	1.15	0.73
	1988-1991	1.67	1.43	1.15	1.57	0.90

The passing vehicles in both years show values consistently less than 0.5, which means the mean readings are less than half of the cut-points (Table 37). 2002 values were slightly less than for 2001, because the concentration means decreased a little, but the cut-points did not change. The newer age groups show lower values, so these vehicles were achieving readings very much lower than their allowable cut-points. The non-dimensional values for NO_x tend to be higher than for HC and CO, which indicates NO_x cut-points to be comparatively stricter than the other cut-points, compared to what the typical passing vehicle can achieve.

Table 39. ASM and Idle Space Mean Non-Dimensional Emissions Readings After Repair

	Age Group	Idle HC (non-dim)	Idle CO (non-dim)	ASM HC (non-dim)	ASM CO (non-dim)	ASM NOx (non dim)
REPAIRED TO PASS	Pre-1972	0.32	0.47	0.38	0.39	0.32
	1972-1981	0.31	0.27	0.30	0.25	0.39
	1982-1987	0.29	0.16	0.31	0.22	0.42
	1988-1991	0.31	0.09	0.33	0.17	0.35
REPAIRED TO C WAIVER	Pre-1972	0.96	0.88	1.14	1.43	0.21
	1972-1981	1.35	0.51	0.91	1.19	0.44
	1982-1987	1.10	0.38	0.81	1.16	0.55
	1988-1991	2.06	0.91	1.19	1.15	0.82
REPAIRED TO Q WAIVER	Pre-1972	0.66	0.65	0.73	1.15	0.30
	1972-1981	0.72	0.41	0.82	1.07	0.46
	1982-1987	0.71	0.32	0.69	0.92	0.60
	1988-1991	0.99	0.58	0.90	0.97	0.75

Only six of the failing values (Table 37) are actually greater than unity, because failure usually only involves one or two failed readings with the other readings being below their cut-points. All of the values are much higher than for passing vehicles, except NO_x for pre-1972 vehicles (as expected). This suggests that when a vehicle fails, it may only fail for one or two emissions, but the other emissions are also probably higher than they should be.

The before-and-after-repair non-dimensional values have been separated into three groups according to their post-repair result. Table 38 is for Before-Repair, and Table 39 is for After-Repair. This data is shown only for the sake of completeness. The comments made in the previous section also apply to these non-dimensional values.

7.8 IM240 Space

7.8.1 Dimensional IM240 Space

Mean emission readings for IM240 inspections on 1992 and newer vehicles are shown in Table 40 to Table 43. These averages have been calculated on the basis of vehicles, and those vehicles that have had multiple inspections were not counted multiple times. Only the 2002 inspections are shown because 2001 included the phase-in period, during which IM240 cut-points were much easier, so including readings from this period would have raised all the 2001 average readings and created a false impression of 2001 and the differences between 2001 and 2002.

Comparing repaired-to-pass readings with readings from vehicles that passed-first-time shows very little difference. So the average passing readings do not seem to be affected by the previous pass/fail history of the vehicles involved.

7.7.2 Non-Dimensional ASM Space and Idle Space

Mean non-dimensional (normalized) emission values for ASM and idle inspections on 1991 and older vehicles are shown in Table 37 to Table 39. The non-dimensional figure has been determined by taking the quotient of the reading and its associated cut-point. Thus a value greater than unity is over the cut-point (failure), and less than unity is below the cut-point (pass). The average non-dimensional reading indicates how well the group is passing, or how badly it is failing.

Table 37. ASM and Idle Space Mean Non-Dimensional Emissions Readings

		Age Group	Idle HC (non-dim)	Idle CO (non-dim)	ASM HC (non-dim)	ASM CO (non-dim)	ASM NOx (non dim)
2001	PASS	Pre-1972	0.32	0.48	0.42	0.34	0.41
		1972-1981	0.29	0.34	0.30	0.24	0.43
		1982-1987	0.28	0.19	0.29	0.20	0.40
		1988-1991	0.31	0.18	0.26	0.17	0.31
2002	PASS	Pre-1972	0.30	0.46	0.39	0.33	0.38
		1972-1981	0.28	0.32	0.29	0.23	0.43
		1982-1987	0.27	0.18	0.30	0.20	0.41
		1988-1991	0.29	0.14	0.28	0.18	0.32
	FAIL*	Pre-1972	0.93	1.10	0.91	0.99	0.31
		1972-1981	1.22	0.70	0.82	0.80	0.53
		1982-1987	1.03	0.55	0.69	0.83	0.64
		1988-1991	1.54	1.22	0.98	1.26	0.76

Table 38. ASM and Idle Space Mean Non-Dimensional Emissions Readings Before Repair

	Age Group	Idle HC (non-dim)	Idle CO (non-dim)	ASM HC (non-dim)	ASM CO (non-dim)	ASM NOx (non dim)
BEFORE REPAIR TO PASS	Pre-1972	0.82	1.10	0.80	0.90	0.33
	1972-1981	1.20	0.75	0.77	0.76	0.57
	1982-1987	1.07	0.59	0.70	0.85	0.71
	1988-1991	1.60	1.31	1.04	1.40	0.84
BEFORE REPAIR TO C WAIVER	Pre-1972	1.15	1.08	1.41	1.49	0.25
	1972-1981	1.79	0.75	1.12	1.27	0.49
	1982-1987	1.38	0.59	0.98	1.39	0.55
	1988-1991	2.58	1.52	1.44	1.62	0.89
BEFORE REPAIR TO Q WAIVER	Pre-1972	0.83	1.05	1.01	1.18	0.31
	1972-1981	1.25	0.80	0.80	1.15	0.54
	1982-1987	1.10	0.61	0.83	1.15	0.73
	1988-1991	1.67	1.43	1.15	1.57	0.90

The passing vehicles in both years show values consistently less than 0.5, which means the mean readings are less than half of the cut-points (Table 37). 2002 values were slightly less than for 2001, because the concentration means decreased a little, but the cut-points did not change. The newer age groups show lower values, so these vehicles were achieving readings very much lower than their allowable cut-points. The non-dimensional values for NO_x tend to be higher than for HC and CO, which indicates NO_x cut-points to be comparatively stricter than the other cut-points, compared to what the typical passing vehicle can achieve.

Table 39. ASM and Idle Space Mean Non-Dimensional Emissions Readings After Repair

	Age Group	Idle HC (non-dim)	Idle CO (non-dim)	ASM HC (non-dim)	ASM CO (non-dim)	ASM NOx (non dim)
REPAIRED TO PASS	Pre-1972	0.32	0.47	0.38	0.39	0.32
	1972-1981	0.31	0.27	0.30	0.25	0.39
	1982-1987	0.29	0.16	0.31	0.22	0.42
	1988-1991	0.31	0.09	0.33	0.17	0.35
REPAIRED TO C WAIVER	Pre-1972	0.96	0.88	1.14	1.43	0.21
	1972-1981	1.35	0.51	0.91	1.19	0.44
	1982-1987	1.10	0.38	0.81	1.16	0.55
	1988-1991	2.06	0.91	1.19	1.15	0.82
REPAIRED TO Q WAIVER	Pre-1972	0.66	0.65	0.73	1.15	0.30
	1972-1981	0.72	0.41	0.82	1.07	0.46
	1982-1987	0.71	0.32	0.69	0.92	0.60
	1988-1991	0.99	0.58	0.90	0.97	0.75

Only six of the failing values (Table 37) are actually greater than unity, because failure usually only involves one or two failed readings with the other readings being below their cut-points. All of the values are much higher than for passing vehicles, except NO_x for pre-1972 vehicles (as expected). This suggests that when a vehicle fails, it may only fail for one or two emissions, but the other emissions are also probably higher than they should be.

The before-and-after-repair non-dimensional values have been separated into three groups according to their post-repair result. Table 38 is for Before-Repair, and Table 39 is for After-Repair. This data is shown only for the sake of completeness. The comments made in the previous section also apply to these non-dimensional values.

7.8 IM240 Space

7.8.1 Dimensional IM240 Space

Mean emission readings for IM240 inspections on 1992 and newer vehicles are shown in Table 40 to Table 43. These averages have been calculated on the basis of vehicles, and those vehicles that have had multiple inspections were not counted multiple times. Only the 2002 inspections are shown because 2001 included the phase-in period, during which IM240 cut-points were much easier, so including readings from this period would have raised all the 2001 average readings and created a false impression of 2001 and the differences between 2001 and 2002.

To calculate mean emission readings in IM240 space is not as simple as for ASM or idle space. The problem was caused by the way that fast-pass readings were initially reported. Another section of this report describes how the fast-pass criteria and reported readings algorithms were changed early in 2002. To derive IM240 means, the first step was to re-report all the earlier fast-pass readings using the new algorithms. This was done for all inspections from September 2001 onwards, and was necessary because many vehicles were first inspected in late 2001 and then returned for final re-inspection in 2002.

For passing inspections, there is a clear difference between Tier 0 and Tier 1 vehicles. (Table 40). Typically, the Tier 1 readings are about half of those for Tier 0 vehicles.

Table 40. IM240 Space Mean Dimensional Emissions Readings of Pass Vehicles

Group	HC (g/km)	CO (g/km)	NO_x (g/km)
Tier 0 Cars	0.23	4.07	0.62
Tier 1 Cars	0.10	2.68	0.33
Tier 0 Trucks	0.33	5.45	0.96
Tier 1 Trucks	0.14	2.91	0.54

A similar comparison can be made between the mean reading from passing vehicles and those from failing vehicles. In each case the failing mean readings are about twice as high as the passing mean readings (Table 41).

Table 41. IM240 Space Mean Dimensional Emissions Readings of Fail Vehicles

Group	HC (g/km)	CO (g/km)	NO_x (g/km)
Tier 0 Cars	0.74	8.92	1.21
Tier 1 Cars	0.47	9.81	0.70
Tier 0 Trucks	0.85	10.75	1.77
Tier 1 Trucks	0.51	8.05	1.68

Within the failed means, there is the generally expected pattern of higher readings for older vehicles, but the failed CO means for passenger cars are actually higher for Tier 1 than for Tier 0. However, overall there is much less difference between Tier 0 and Tier 1 for these failed inspection means than for the passed inspection means.

The before and after repair means for vehicles that were repaired have been separated into three groups, dependent on their final result of P, C or Q. The before-repair condition is shown in tables Table 42, and the after-repair condition in Table 43. Some vehicles that failed did not

subsequently achieve a pass or conditional pass; they contribute to the failure mean readings shown in Table 41, but are not shown separately.

Table 42. IM240 Space Mean Dimensional Emissions Readings of Before-Repair Vehicles

	BEFORE REPAIR TO PASS			BEFORE REPAIR TO COST WAIVER			BEFORE REPAIR TO Q WAIVER		
Group	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)
Tier 0 Cars	0.74	9.27	1.27	1.01	10.15	1.45	0.95	10.35	1.33
Tier 1 Cars	0.41	9.94	0.65	0.90	9.50	1.09	0.61	7.77	1.03
Tier 0 Trucks	0.83	10.86	1.80	1.16	12.51	1.98	0.99	10.87	1.89
Tier 1 Trucks	0.47	7.75	1.63	0.63	11.34	2.05	0.46	8.11	1.84

There do not appear to be any compelling differences in the mean before-repair readings for vehicles that were subsequently repaired to achieve a pass, a cost waiver, or a qualified waiver. The before-repair mean readings for Tier 0 cars and trucks that were subsequently repaired to pass are a little lower than for those vehicles that only achieved a final waiver. But this difference does not seem enough to indicate any intentional behaviour choices being made in the way that was discussed for older vehicles that are inspected using ASM + idle.

Table 43. IM240 Space Mean Dimensional Emissions Readings of After-Repair Vehicles

	REPAIR TO PASS			REPAIR TO COST WAIVER			REPAIR TO Q WAIVER		
Group	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)
Tier 0 Cars	0.25	3.49	0.61	0.88	8.74	1.24	0.69	8.17	1.08
Tier 1 Cars	0.13	2.92	0.30	1.23	8.71	0.86	0.61	6.84	0.88
Tier 0 Trucks	0.34	4.57	0.89	0.99	11.51	1.86	0.75	8.87	1.55
Tier 1 Trucks	0.17	2.91	0.73	0.76	7.14	1.97	0.38	5.45	1.72

After repair, the mean readings for passing vehicles are all substantially lower than for waivered vehicles. In fact the waivered mean readings are typically two or three times higher than for vehicles repaired to pass.

Almost all the after-repair readings for C waivered vehicles were higher than those for Q waivered. Thus, in the same way as described for older vehicles, Q waivers deliver more emissions benefit than C waivers, but not as much as a real pass. However, a Q waiver could indicate an inadequate diagnosis or faulty repair.

To calculate mean emission readings in IM240 space is not as simple as for ASM or idle space. The problem was caused by the way that fast-pass readings were initially reported. Another section of this report describes how the fast-pass criteria and reported readings algorithms were changed early in 2002. To derive IM240 means, the first step was to re-report all the earlier fast-pass readings using the new algorithms. This was done for all inspections from September 2001 onwards, and was necessary because many vehicles were first inspected in late 2001 and then returned for final re-inspection in 2002.

For passing inspections, there is a clear difference between Tier 0 and Tier 1 vehicles. (Table 40). Typically, the Tier 1 readings are about half of those for Tier 0 vehicles.

Table 40. IM240 Space Mean Dimensional Emissions Readings of Pass Vehicles

Group	HC (g/km)	CO (g/km)	NO_x (g/km)
Tier 0 Cars	0.23	4.07	0.62
Tier 1 Cars	0.10	2.68	0.33
Tier 0 Trucks	0.33	5.45	0.96
Tier 1 Trucks	0.14	2.91	0.54

A similar comparison can be made between the mean reading from passing vehicles and those from failing vehicles. In each case the failing mean readings are about twice as high as the passing mean readings (Table 41).

Table 41. IM240 Space Mean Dimensional Emissions Readings of Fail Vehicles

Group	HC (g/km)	CO (g/km)	NO_x (g/km)
Tier 0 Cars	0.74	8.92	1.21
Tier 1 Cars	0.47	9.81	0.70
Tier 0 Trucks	0.85	10.75	1.77
Tier 1 Trucks	0.51	8.05	1.68

Within the failed means, there is the generally expected pattern of higher readings for older vehicles, but the failed CO means for passenger cars are actually higher for Tier 1 than for Tier 0. However, overall there is much less difference between Tier 0 and Tier 1 for these failed inspection means than for the passed inspection means.

The before and after repair means for vehicles that were repaired have been separated into three groups, dependent on their final result of P, C or Q. The before-repair condition is shown in tables Table 42, and the after-repair condition in Table 43. Some vehicles that failed did not

subsequently achieve a pass or conditional pass; they contribute to the failure mean readings shown in Table 41, but are not shown separately.

Table 42. IM240 Space Mean Dimensional Emissions Readings of Before-Repair Vehicles

	BEFORE REPAIR TO PASS			BEFORE REPAIR TO COST WAIVER			BEFORE REPAIR TO Q WAIVER		
Group	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)
Tier 0 Cars	0.74	9.27	1.27	1.01	10.15	1.45	0.95	10.35	1.33
Tier 1 Cars	0.41	9.94	0.65	0.90	9.50	1.09	0.61	7.77	1.03
Tier 0 Trucks	0.83	10.86	1.80	1.16	12.51	1.98	0.99	10.87	1.89
Tier 1 Trucks	0.47	7.75	1.63	0.63	11.34	2.05	0.46	8.11	1.84

There do not appear to be any compelling differences in the mean before-repair readings for vehicles that were subsequently repaired to achieve a pass, a cost waiver, or a qualified waiver. The before-repair mean readings for Tier 0 cars and trucks that were subsequently repaired to pass are a little lower than for those vehicles that only achieved a final waiver. But this difference does not seem enough to indicate any intentional behaviour choices being made in the way that was discussed for older vehicles that are inspected using ASM + idle.

Table 43. IM240 Space Mean Dimensional Emissions Readings of After-Repair Vehicles

	REPAIR TO PASS			REPAIR TO COST WAIVER			REPAIR TO Q WAIVER		
Group	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)	HC (g/km)	CO (g/km)	NOx (g/km)
Tier 0 Cars	0.25	3.49	0.61	0.88	8.74	1.24	0.69	8.17	1.08
Tier 1 Cars	0.13	2.92	0.30	1.23	8.71	0.86	0.61	6.84	0.88
Tier 0 Trucks	0.34	4.57	0.89	0.99	11.51	1.86	0.75	8.87	1.55
Tier 1 Trucks	0.17	2.91	0.73	0.76	7.14	1.97	0.38	5.45	1.72

After repair, the mean readings for passing vehicles are all substantially lower than for waivered vehicles. In fact the waivered mean readings are typically two or three times higher than for vehicles repaired to pass.

Almost all the after-repair readings for C waivered vehicles were higher than those for Q waivered. Thus, in the same way as described for older vehicles, Q waivers deliver more emissions benefit than C waivers, but not as much as a real pass. However, a Q waiver could indicate an inadequate diagnosis or faulty repair.

Comparing repaired-to-pass readings with readings from vehicles that passed-first-time shows very little difference. So the average passing readings do not seem to be affected by the previous pass/fail history of the vehicles involved. This is the same observation as was made for older vehicles.

7.8.2 NON-DIMENSIONAL IM240 SPACE

Mean non-dimensional emission values for IM240 inspections on 1992 and newer vehicles are shown in Table 44 to Table 47. Non-dimensionalisation has been accomplished by taking the quotient of the reported reading and the associated cut-point. Thus a value greater than unity is over the cut-point (failure), and less than unity is below the cut-point (pass). The average non-dimensional reading indicates how well the group is passing, or how badly it is failing.

The passing vehicles show values usually less than 0.5 which means the mean readings are usually less than half of the cut-points (Table 44). There is no clear difference between the non-dimensional values for HC, CO and NO_x, which indicates that all cut-points to be about equally stringent in terms of what the typical passing vehicle can achieve.

Table 44. IM240 Space Mean Non-Dimensional Emissions Readings of Pass Vehicles

Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	0.45	0.44	0.50
Tier 1 Cars	0.25	0.37	0.32
Tier 0 Trucks	0.43	0.47	0.57
Tier 1 Trucks	0.27	0.32	0.42

Most of the failing values (Table 45) are actually greater than unity. Three of the values are less than one because overall failure can involve one or two passed readings. All of the values are much higher than for passing vehicles. This suggests that when a vehicle fails, it may only fail for one or two emissions, but the other emissions are also probably higher than they should be.

Table 45. IM240 Space Mean Non-Dimensional Emissions Readings of Fail Vehicles

Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	1.48	0.96	0.97
Tier 1 Cars	1.09	1.38	0.67
Tier 0 Trucks	1.16	0.95	1.20
Tier 1 Trucks	0.89	0.85	1.36

The before-and-after-repair non-dimensional values have been separated into three groups. by their repaired result. Table 46 are before repair, and Table 47 are after repair. This data is shown only for the sake of completeness. The comments made in the previous section also apply to these non-dimensional values.

Table 46. IM240 Space Mean Non-Dimensional Emissions Readings of Before-Repair Vehicles

	BEFORE REPAIR TO PASS			BEFORE REPAIR TO COST WAIVER			BEFORE REPAIR TO Q WAIVER		
Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	1.48	1.00	1.02	2.02	1.09	1.17	1.90	1.11	1.08
Tier 1 Cars	0.96	1.39	0.62	1.94	1.25	0.95	1.36	1.07	0.95
Tier 0 Trucks	1.12	0.95	1.22	1.64	1.14	1.40	1.49	1.05	1.37
Tier 1 Trucks	0.82	0.82	1.32	1.15	1.21	1.73	0.84	0.86	1.56

Table 47. IM240 Space Mean Non-Dimensional Emissions Readings of After-Repair Vehicles

	REPAIR TO PASS			REPAIR TO COST WAIVER			REPAIR TO Q WAIVER		
Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	0.51	0.38	0.51	1.80	0.96	1.02	1.39	0.88	0.88
Tier 1 Cars	0.33	0.45	0.31	3.15	1.19	0.82	1.42	1.01	0.85
Tier 0 Trucks	0.45	0.40	0.57	1.42	1.03	1.33	1.11	0.85	1.14
Tier 1 Trucks	0.32	0.32	0.56	1.43	0.70	1.69	0.69	0.57	1.44

7.9 D147 Opacity Space

Table 48 shows the numbers of, and the average opacities for diesel inspections that passed, failed, were repaired, or were waivered. Compared to gasoline vehicles, there are very few waivers. Almost all diesel vehicles that failed were either repaired to pass, have already been removed from use, or are still awaiting repair.

The average before-repair opacity for failing vehicles was 52.9% for older vehicles and 54.9% for newer vehicles. After being repaired to pass re-inspection the average opacities were reduced to 14.7% and 9.5% respectively. These after-repair opacities are only slightly higher than the average passed inspection opacities, which indicates that repairs have restored the smoke emissions down to about the same level as from vehicles that never failed.

Comparing repaired-to-pass readings with readings from vehicles that passed-first-time shows very little difference. So the average passing readings do not seem to be affected by the previous pass/fail history of the vehicles involved. This is the same observation as was made for older vehicles.

7.8.2 NON-DIMENSIONAL IM240 SPACE

Mean non-dimensional emission values for IM240 inspections on 1992 and newer vehicles are shown in Table 44 to Table 47. Non-dimensionalisation has been accomplished by taking the quotient of the reported reading and the associated cut-point. Thus a value greater than unity is over the cut-point (failure), and less than unity is below the cut-point (pass). The average non-dimensional reading indicates how well the group is passing, or how badly it is failing.

The passing vehicles show values usually less than 0.5 which means the mean readings are usually less than half of the cut-points (Table 44). There is no clear difference between the non-dimensional values for HC, CO and NO_x, which indicates that all cut-points to be about equally stringent in terms of what the typical passing vehicle can achieve.

Table 44. IM240 Space Mean Non-Dimensional Emissions Readings of Pass Vehicles

Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	0.45	0.44	0.50
Tier 1 Cars	0.25	0.37	0.32
Tier 0 Trucks	0.43	0.47	0.57
Tier 1 Trucks	0.27	0.32	0.42

Most of the failing values (Table 45) are actually greater than unity. Three of the values are less than one because overall failure can involve one or two passed readings. All of the values are much higher than for passing vehicles. This suggests that when a vehicle fails, it may only fail for one or two emissions, but the other emissions are also probably higher than they should be.

Table 45. IM240 Space Mean Non-Dimensional Emissions Readings of Fail Vehicles

Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	1.48	0.96	0.97
Tier 1 Cars	1.09	1.36	0.67
Tier 0 Trucks	1.16	0.95	1.20
Tier 1 Trucks	0.89	0.85	1.36

The before-and-after-repair non-dimensional values have been separated into three groups. by their repaired result. Table 46 are before repair, and Table 47 are after repair. This data is shown only for the sake of completeness. The comments made in the previous section also apply to these non-dimensional values.

Table 46. IM240 Space Mean Non-Dimensional Emissions Readings of Before-Repair Vehicles

	BEFORE REPAIR TO PASS			BEFORE REPAIR TO COST WAIVER			BEFORE REPAIR TO Q WAIVER		
Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	1.48	1.00	1.02	2.02	1.09	1.17	1.90	1.11	1.08
Tier 1 Cars	0.96	1.39	0.62	1.94	1.25	0.95	1.36	1.07	0.95
Tier 0 Trucks	1.12	0.95	1.22	1.64	1.14	1.40	1.49	1.05	1.37
Tier 1 Trucks	0.82	0.82	1.32	1.15	1.21	1.73	0.84	0.86	1.56

Table 47. IM240 Space Mean Non-Dimensional Emissions Readings of After-Repair Vehicles

	REPAIR TO PASS			REPAIR TO COST WAIVER			REPAIR TO Q WAIVER		
Group	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)	HC (Non-dim)	CO (Non-dim)	NO_x (Non-dim)
Tier 0 Cars	0.51	0.38	0.51	1.80	0.96	1.02	1.39	0.88	0.88
Tier 1 Cars	0.33	0.45	0.31	3.15	1.19	0.82	1.42	1.01	0.85
Tier 0 Trucks	0.45	0.40	0.57	1.42	1.03	1.33	1.11	0.85	1.14
Tier 1 Trucks	0.32	0.32	0.56	1.43	0.70	1.69	0.69	0.57	1.44

7.9 D147 Opacity Space

Table 48 shows the numbers of, and the average opacities for diesel inspections that passed, failed, were repaired, or were waivered. Compared to gasoline vehicles, there are very few waivers. Almost all diesel vehicles that failed were either repaired to pass, have already been removed from use, or are still awaiting repair.

The average before-repair opacity for failing vehicles was 52.9% for older vehicles and 54.9% for newer vehicles. After being repaired to pass re-inspection the average opacities were reduced to 14.7% and 9.5% respectively. These after-repair opacities are only slightly higher than the average passed inspection opacities, which indicates that repairs have restored the smoke emissions down to about the same level as from vehicles that never failed.

Table 48. D147 Opacity Space

	1991 and Older	1992 and Newer
	Number of Vehicles	
Inspected	10,111	10,955
Passed	9,775	10,899
Failed	1,544	178
Waivered	52	2
Repaired to pass	1,181	159
	Average Opacity Reading (%)	
All inspections	17.4	7.3
Passed inspections	12.5	6.1
Failed inspections	53.5	59.4
Waivers	52.0	87.6
Before-repair	52.9	54.9
After-repair	14.7	9.5

Table 48. D147 Opacity Space

	1991 and Older	1992 and Newer
	Number of Vehicles	
Inspected	10,111	10,955
Passed	9,775	10,899
Failed	1,544	178
Waivered	52	2
Repaired to pass	1,181	159
	Average Opacity Reading (%)	
All inspections	17.4	7.3
Passed inspections	12.5	6.1
Failed inspections	53.5	59.4
Waivers	52.0	87.6
Before-repair	52.9	54.9
After-repair	14.7	9.5

Appendices

A. Glossary

B. IM240 Fast Pass Criteria

A. GLOSSARY

Advisory	A notice concerning a fault with a vehicle. AirCare advisories pertain to missing or tampered catalytic converters for pre-1988 model year vehicles, and to OBD DTCs for 1998 and newer vehicles.
AirCare I	The inspection and maintenance program established for Light-Duty Vehicles in GVRD and LVRD effective September 1st, 1992
AirCare II	Implementation of changes to the AirCare I Program effective January 1st, 2001
AirCare Research Centre	A mass-emissions laboratory used for research, vehicle diagnostics and conflict resolution.
AirCare-eligible	Vehicle requires an AirCare emissions inspection prior to re-licensing.
AirCare staff	Refers to employees of PVTT or Envirotest Canada
ASM 2525	Acceleration Simulation Mode test procedure, also referred to as simply ASM. It consists of driving the vehicle on a dynamometer at a constant speed of 25mph, with a constant load equal to 25% of the maximum FTP load, while monitoring the exhaust emissions.
ASM space	The expression of emissions performance and reductions entirely in terms of concentrations measured as part of an ASM test.
Audit	A quality control process to check and determine if the inspection centres equipment is properly calibrated and maintained
Average passing vehicle	Values represents the average readings for passing vehicles of the same year, type (car or truck), make and engine as inspected vehicle, calculated from actual AirCare test results.
BAR 97	The BAR (Bureau of Automotive Repair) 1997 specification is for equipment used to perform steady state, loaded-mode emissions tests (ASM 2525, ASM 5015). BAR 97 establishes performance criteria for the equipment used to perform the test.
Base inertia	The mechanical inertia of a dynamometer in the absence of any electrically simulated inertia.
Beer-Lambert Law	The Beer-Lambert law is the linear relationship between absorbanceof light and the concentration of an absorbing species
Bureau of Automotive Repair	The Bureau of Automotive Repair (BAR) is part of the California Department of Consumer Affairs. BAR manages the implementation of the motor vehicle Inspection and Maintenance Program.
C waiver	Cost Waiver, a conditional pass based on required repair costs exceeding the repair cost limits for the vehicle
Calibration	A set of procedures to ensure an instruments accuracy and provide quality control assurance
Calibration gas	Pressurized gas containing exhaust gas components blended to exact tolerances and certified to be accurate within a specified tolerance. Gas analysers used by AirCare inspection centres and AirCare Certified Repair Centres are required to be calibrated at regular intervals with calibration gas to ensure accurate measurements.

Certification test	EPA75 or FTP, the test that certifies a vehicle conforms to its federal mandated emission design limits
Check engine light	An illuminated light on the dashboard warning the driver that a problem exists with the vehicle. Also known as the Malfunction Indicator Lamp, or MIL.
Chemiluminescence	A process used in NO_x analysers, where NO and ozone are mixed in a reaction chamber producing light in proportion to the amount of NO
Closed-loop fuel control	System in which the fuel/air ratio in the engine is carefully controlled to optimize emissions performance. A closed-loop system uses oxygen sensor(s) to provide a feedback control signal.
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Coastdown	A check to ensure a dynamometer is accurately correcting for parasitic losses in bearings, belts and other sources of friction.
Cold start	Starting of a vehicle after a predetermined cold soak period
Collector	Licensing status issued by ICBC. To qualify for collector status, a vehicle must be at least 25 years old for most cars, or; at least 15 years old if it's a limited production vehicle or; at least 15 years old and from a source which has not manufactured vehicles of any kind for at least five years.
Composite standards	Cut-points which apply to a full-duration IM240 inspection cycle
Conditional pass	Conditional passes are waivers that are granted on the basis of repair and cost information submitted by a certified repair centre.
Constant volume sampler	A constant volume sampling system, which maintains a constant total flow rate of vehicle exhaust plus dilution air. A normal part of a mass-emissions measuring system.
Cut point	For each pollutant, the emissions level above which a car is considered to have failed the emissions test for that pollutant.
D147	Enhanced diesel emissions test, measures opacity during a transient drive cycle
Driving cycle	A driving schedule to simulate real world conditions, periods of acceleration, deceleration, cruise, and idle
DTC	Diagnostic trouble code stored by the OBD II system
Dynamometer	A treadmill-like device that simulates vehicle inertia and road load to derive results under conditions similar to normal driving.
EGR	Exhaust Gas Recirculation. A method of reducing NO_x emissions by recirculating some of the exhaust gas into the intake charge.
Emission factors	For mobile source emissions, emission factors are mass of each pollutant per unit distance (e.g., grams per kilometre)
EMS	Emissions measuring system

Excess-emitting	Vehicles that produce emissions higher than established AirCare emission cut-points.
Exempt	Vehicles that do not require an AirCare inspection
Expiry date	The last day an AirCare test is valid for re-licensing.
Failure modes	The various manners or areas that a vehicle can fail an emissions inspection
Fast pass	A protocol that allows vehicles operating well within their allowed limits to terminate inspection early to increase throughput
FID	Flame ionization detector, an analyzer that measures total hydrocarbon emissions
Fidle code	A code number that corresponds to a specific reason for performing an idle test on a vehicle rather than a dynamometer inspection.
First generation OBD	First vehicle's equipped with an onboard engine control computer to provide diagnostic data to assist a technician in determining were a fault probably lies in any monitored circuit
FTP test	Federal Test Procedure. A certification test for measuring the tailpipe and evaporative emissions from new vehicles
Full duration IM240	An IM240 inspection that went 240 seconds without fast-passing
FVRD	Fraser Valley Regional District
GVRD	Greater Vancouver Regional District
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
Heavy duty truck	Vehicle with GVWR greater than 8500 lb, curb weight greater than 6000 lb and frontal area greater than 45 square feet.
High idle	An idle speed typically between 2000&2500 rpm
ICBC	Insurance Corporation of British Columbia
Idle space	The expression of emissions performance and reductions entirely in terms of concentrations measured as part of an idle test.
Idle test	An emissions test performed under idle conditions. (maximum 1150 rpm)
IM240	A transient emission test procedure established by the U.S. EPA, and derived from the Federal Test Procedure.
Light duty truck	Vehicle with GVWR less than or equal to 8500 lb, curb weight less than or equal to 6000 lb and frontal area less than or equal to 45 square feet designed for the transportation of goods or the carriage of more than 12 passengers.
Malfunction indicator lamp	The instrument panel light used by the on-board diagnostic system to notify the vehicle operator of an engine or emission control related fault.

MAP sensor	Manifold Absolute Pressure sensor, informs PCM of engine load
Mass emissions inventory	Estimates of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year.
Master pass cap	A gas cap calibrated to consistently pass a leak test.
Megagram	1 Mg = 10^6g = 1000kg = 1 tonne
MMT	Methylcyclopentadienyl manganese tricarbonyl, is a manganese compound which, when burned in automobile engines, results in manganese air pollution and O2 sensor and/or catalyst contamination. It is used as an octane rating enhancer.
Mode length	The time taken to complete a phase of an inspection test
Model year	Vehicles are certified for sale, marketed and later registered as certain model year that indicates the year a vehicle was produced and offered for sale. A model year run must include the January 1st of the calendar year corresponding to the model year but cannot extend so as to include two January 1st dates.
N_2	Nitrogen
NDIR	Non-Dispersive Infra Red
NIST	National Institute of Standards & Technology
NO_x	Oxides Of Nitrogen
O2	Oxygen
OBD II	On-Board Diagnostics II. This system continuously monitors the emission control and emission-related systems and records any defects in up to 50 different components. This allows Service Technicians to diagnose intermittent engine problems, to help reduce service time and cost.
Off-cycle operation	Operating a vehicle at a speed and load condition not included in the FTP driving cycle.
On-board computer	Microprocessor that controls engine and emission control functions.
Opacity	The amount of light obscured by particulate matter. Clear window glass has zero opacity, while a brick wall is 100 percent opaque. Opacity is a surrogate for particulate matter emissions.
Oxygen sensor	A device used to measure the oxygen content of vehicle exhaust gases. The signal is fed to the on-board computer which regulates the fuel-air mixture for optimum exhaust gas reduction.
Passenger vehicle	A motor vehicle designed for moving people
Phase 2	The second part of IM240; starts at 94 second and lasts for 147 seconds
Phase-in standards	Temporary standards used during a set period of time in order to monitor the performance of the fleet prior to implementing the final standards.

PM	Solid or liquid particles of soot, dust, smoke, fumes, and aerosols.
ppm	Gas concentration measured in parts per million
Program Administration Office	Organization that administers the AirCare program. Currently as a subsidiary of Translink, named PVTT
PVTT	Pacific Vehicle Testing Technologies, an operating subsidiary of TransLink. PVTT staff administer the AirCare program.
Q waiver	Qualified waiver, a conditional pass where the Repair Data Form indicates no remaining emissions related defects on the vehicle
Quality Repair Award	Award given to technicians whose repair efficiency meets a predetermined standard
Registered GVW	The gross vehicle weight that the vehicle has been registered and licensed for
Regulated pollutants	CO, HC, NO_x, and PM are the regulated pollutants for motor vehicles
Repair Advisory Committee	RAC, a committee comprising repair industry and AirCare representatives that discuss issues involving the repair industry
Repair cost limit	The maximum dollar amount needed to be spent on repairs at a certified shop to qualify for a cost waiver
Repair data form	An on-line form completed by repair technician to report the repairs performed and outstanding items still in need of repair.
Repair Effectiveness Index	An objective assessment of the effectiveness of an emissions repair based on emissions reductions achieved
RepairNet	An Internet-based application providing certified repair centres and technicians with access to all vehicle inspection and repair records. Within the RepairNet, AirCare technicians and repair centres also submit vehicle repair data on-line.
Sample dilution	Dilution of an exhaust gas sample to the point where the sample cannot be considered valid.
Sample test	A full-duration IM240 test performed after a mandatory AirCare inspection. Vehicles that meet an established set of criteria receive a sample test in order to gather more comprehensive vehicle emission data and to calculate AirCare benefits.
Scan tool	A hand held computer that is plugged into a vehicle's data link connector allowing a technician to read diagnostic trouble codes, readiness status, and other information collected by the OBD system.
Scrap-it program	A vehicle retirement program that recycles vehicles in exchange for various incentives.
Second-by-second readings	Readings recorded every second of an emissions test and used to observe trends and provide technicians with valuable diagnostic data
Show cause hearing	Part of a process for suspending on decertifying a technician and/or repair facility
Tampering	The removal or disabling of any emission control device, that would potentially increase a vehicle's exhaust emissions

Test trace	The on-screen representation of the required driving cycle
Three-way catalytic converter	A catalytic converter that contains the elements to both reduce oxides of nitrogen and oxidize both hydrocarbons and carbon monoxide.
Tier 0	Tailpipe standards beginning with model-year 1981in the United States and were phased out by model-year 1995 for passenger cars and most light duty trucks.
Tier 1	Tailpipe standards that were phased in for 40% of 1994 models, 80% of 1995 models and 100% of 1996 models.
Transient inspection	An emissions test performed under loads and speeds that vary from second to second during the test.
Trouble code	A code number generated by a vehicle's onboard computer that corresponds to a specific fault.
U.S. EPA	The United States Environmental Protection Agency. The mission of the U.S. EPA is to protect human health and to safeguard the natural environment--air, water, and land--upon which life depends.
Vehicle type	Description used to determine the primary use of a motor vehicle and to determine it's emission classification
Vintage	Licensing status issued by ICBC. The vehicle must be: at least 30 years old, owned as a collector's item, maintained as close as possible to its original condition with original parts, and mechanically sound.
VkmT	The product of the number of vehicles multiplied by their annual distance driven in kilometres
Void	Rendering a test result invalid for the purposes of re-licensing.
Volatile Organic Compounds	Hydrocarbon compounds that exist in the ambient air. VOCs contribute to the formation of smog and/or may themselves be toxic. VOC emissions are a major precursor to the formation of ozone.
Waiver	Waivers for emissions compliance are granted when the vehicle fails re-inspection after having been repaired at a certified repair centre
Zeroing	Calibration procedure to ensure the accuracy of an instruments zero point

B. IM240 FAST PASS CRITERIA

Fast Pass Criteria

The objective of fast-pass standards is to accurately identify vehicles that would pass a full-duration IM240 with minimal errors of omission.

EPA fast-pass provisions allow for test termination at the 30-second point, despite the fact that the driving cycle to that point is not very challenging to the engine/emission control system.

EPA fast-pass criteria were developed from a set of full-duration tests, using the cumulative grams of each pollutant at each second for the best 10% of vehicles that failed according to composite emission standards.

After extensive analysis of the full-duration sample tests, it was agreed that in order for a vehicle to be declared "clean" after only 30 seconds, its results should be exemplary, not simply adequate. Thus it was decided that an early fast-pass would be awarded only if the cumulative grams were significantly below the EPA criteria.

The IM240 fast-pass criteria were divided into 3 phases:

30-183 seconds

184-219 seconds

220-239 seconds

In order to achieve a fast-pass, the cumulative grams for HC, CO and NO_x must be less than 70% of the EPA values for the period 30-183 seconds, and 90% for the period 184-219 seconds. From the 220 second mark, the EPA criteria are used without alteration.

Similar logic was applied to Phase 2 fast-pass criteria.

Fast Pass Emission Results Reporting

It is difficult to express the test results for a fast-pass on an inspection report because the vehicle has negotiated only a portion of the cycle. Dividing the grams of each pollutant by the actual distance travelled can sometimes exceed the composite standard. An alternative approach, that was initially adopted for the AirCare IM240, was to divide the fast-pass grams by the full IM240 distance. But this always yields an artificially low number.

With the new fast pass criteria implemented, a new method of reporting the fast pass emissions was also introduced. The cumulative emission up to the fast-pass second is recorded and then divided by the fast-pass cut-point at that second. This non-dimensional reading is then multiplied by a *factor*. For example, a vehicle that passes at 56 second will have a *factor* of 0.7 because the BC cut-point at that instant is 70% of the EPA standards. The factored reading is

then multiplied by the composite standard to give the equivalent full duration reading. So that if the HC reading at 56 second is 2 grams and the cut-point at that second is 4 grams. The non-dimensional reading will be 0.5. Multiplying the non-dimensional reading by 0.7 gives 0.35, which is the factored non-dimensional reading. Assuming the final composite standard is 1.5 g/km, the equivalent full duration reading will be 0.35 of the 1.5 g/km, which is 0.525 g/km.